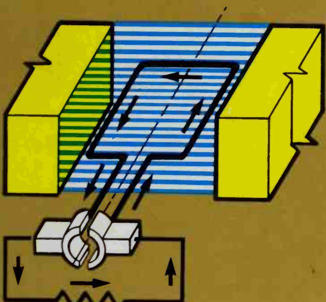
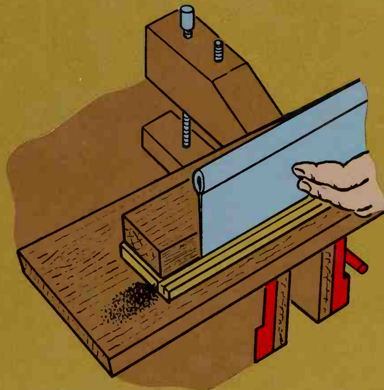
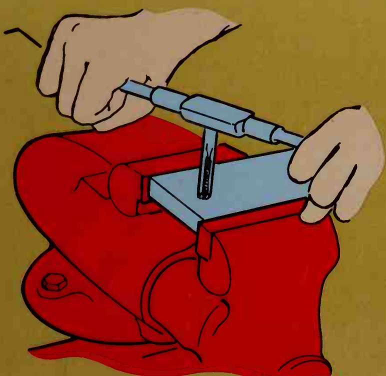
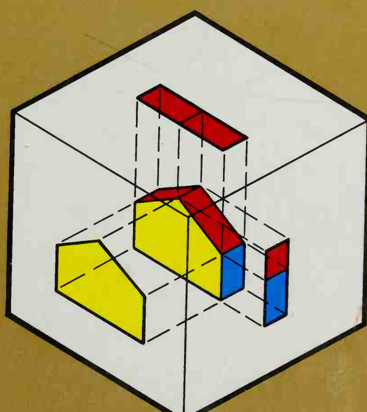
modern GENERAL SHOP

Drafting · Woodworking · Metalworking · Electricity









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Modern
general shop

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Goodheart Willcox's BUILD-A-COURSE® Series

drafting

by

WALTER C. BROWN

Professor, Division of Technology
Arizona State University, Tempe

Books in Build-A-Course® Series

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INTRODUCTION

DRAFTING is one of a series planned specifically for Technology Education or Industrial Arts General Shop courses. It is designed to provide a broad experience in drafting and to enable you to develop the necessary skills to use drafting effectively. This book is intended to teach you to communicate and express ideas in an understandable and accurate manner.

DRAFTING progresses systematically through the skills and informational content basic to an understanding of drafting. In addition to a broad coverage of industrial activities, also included are computer graphics, charts, graphs, maps, and metrics.

It is the author's belief, confirmed by many other instructors, that students want to work with the tools and materials of industry when they come to the shop or drafting room. To make the most of this interest factor, instrument usage and drafting fundamentals are introduced in Unit 1.

Freehand sketching is then presented in the second unit to acquaint you with this important phase of drafting. This will enable you to make use of sketching along with instrument drafting in the remaining units.

It is hoped that DRAFTING will provide students with valuable consumer knowledge and will make drafting a meaningful experience for them in their avocational and career activities.

Walter C. Brown

All manufactured products were first created on the drawing board. (Rohr Industries, Inc.)

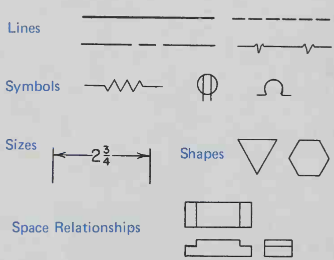
CONTENTS

Unit 1
INTRODUCTION TO DRAFTING

After studying this unit, you will know:
1. What is drafting.
2. How we can use drafting, now and later.
3. What are some of the basic skills in the field of drafting.

A CHAT WITH YOUR INSTRUCTOR

You are about to begin an interesting and fascinating study of another language. Had you thought of drafting in this way? In a very real sense, this is true. It is a means of communication that is often referred to as the "language of industry." It is not a "spoken" language; it is a "graphic" language of:



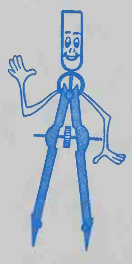
With changes in the units of measurements and the notes, it can be understood equally well by a drafter in Buenos Aires, Paris, or Tokyo. Drafting is the language every technical person uses to communicate ideas clearly and concisely to others. It is a process of thinking, planning and setting thoughts down on paper in graphic form. These forms appear as one of several kinds of drawings: multiview, pictorial, pattern, charts, maps, or schematics. The language of drafting is essential to the communication of ideas.

Almost before you realize it, you will be using this language.

IMPORTANCE OF DRAFTING

Most manufactured products and all major buildings were first created on a drawing board. Before your school building could be constructed, or the machines in your school shop manufactured, many hours were spent in preparing detailed drawings. Industry, as we know it today, could not exist without a quick and economical means of communicating its dreams into reality.

Have you ever stopped to think that before your family car was built it was first a drawing – not just the car as we see it, but every bolt, pin, shaft, cylinder and detail in it. Imagine the number of hours spent preparing the drawings for a jet aircraft. Yes, drafters had to draw every detail before it could be built, and do you know that not one of those drafters was born with a knowledge of drawing!



"Hi! I'm Drafty. I'll be around from time to time with pointers and helpful suggestions."

WHO USES DRAFTING?

A thorough knowledge of drafting is essential to the skilled worker, the technician, and the engineer.

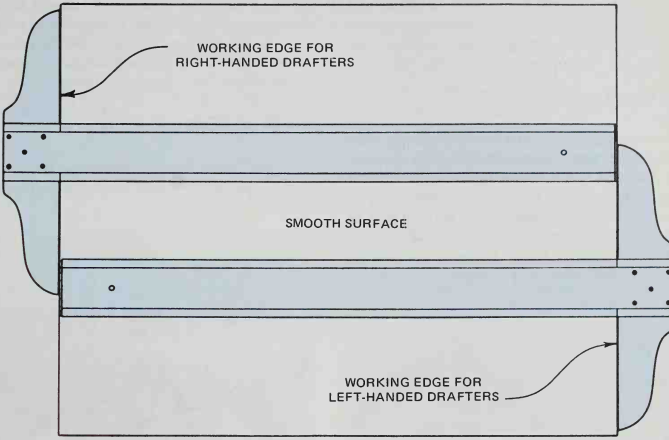


Fig. 1-1. Drawing board showing location of T-square.

It is also of value to the hobbyist and homemaker as he or she undertakes jobs in the home workshop and around the house.

Some of your classmates, perhaps even yourself, may become full-time technical workers in the field of drafting. Many of you will use your knowledge of drafting indirectly in your work. All of you will use products of industry, and a knowledge of drafting will be to your advantage.

Everything you do in the industrial arts shop will depend in part upon your ability to sketch, draw and read drawings. You can also put your knowledge of drafting to work in your other school subjects when you have jobs to do, such as drawing a chart or a graph.

SELECTION AND CARE OF DRAWING BOARDS

There are at least two requirements of a good drawing board: a smooth surface and a straight working edge. See Fig. 1-1. In making drawing boards, both white pine and basswood are used extensively, because their uniform grain textures provide a smooth drawing surface. Some boards or drafting table tops are made of hardwood with a vinyl overlay cover to provide an excellent drawing surface. Since the edge of a drawing board is the reference line for all drawings, it is essential that it be a straight edge. Drawing boards are made in a variety of sizes; the 16 x 22 in. or the 18 x 24 in. size will be suitable for most work.

Skilled craftworkers, technicians and engineers are known in part by the care they give their tools and equipment. You should avoid marring the surface of your drawing board with pencil marks. Use drafting tape for fastening drawing paper to the board.

DRAWING PAPERS

Drawing papers are available in a number of colors and sizes. The drafter selects the color and size most suited for the purpose. Colors ordinarily used are cream, buff, light green, white. Common sizes are:

English	Metric
A 8 1/2 x 11 in.	A4 210 x 297 mm
B 11 x 17 in.	A3 297 x 420 mm
C 17 x 22 in.	A2 420 x 594 mm

For your use in this course, size A (A4 metric) paper should be used. It can be assembled in your notebook after your drawing has been checked. Your instructor will indicate color of paper you should use.

THE T–SQUARE

The T-square consists of a head and a blade, made of hardwood, which are fastened together securely. Some T-squares have blades with plastic edges which permit a better view of the work. Fig. 1-2. The T-square is held firmly against the working edge of the drawing board, Fig. 1-2. It is used for squaring the paper on the board before fastening, for drawing horizontal lines, and as a straight edge for the triangles.

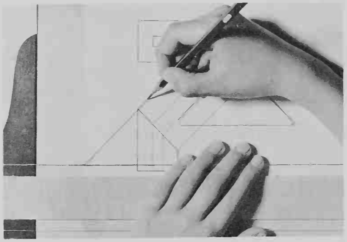


Fig. 1-2. T-square is held firmly against working edge of drawing board.

The drafting tables in some schools and industries are equipped with the parallel rule, Fig. 1-3, or the drafting machine, Fig. 1-4. The parallel rule takes the place of the T-square and moves up and down the drawing surface while remaining in a parallel position. Triangles are used along the straightedge as with the T-square. The drafting machine comes equipped with two adjustable scales or straightedges and serves the purpose of both the T-square and triangles.

Fig. 1-3. Industrial drafting room equipped with parallel-ruling straightedge. (Anderson Engineering Div.)

DRAWING PENCILS

Did you know that drafters do not buy just any pencil? They select pencils according to the grade (hardness) of the leads and sharpen them in a way that will help them produce quality work. There are eighteen grades of pencil leads from which to select. However, few drafters use this many. Fig. 1-5 shows the grades of drawing pencil leads and their suggested uses.

Fig. 1-4. A drafting machine in use in an industrial drafting room. (Signal Oil and Gas Co.)

Drawing pencils may be purchased as wood cased pencils or as mechanical lead holders, Fig. 1-6. Leads for mechanical holders come in the same size as wood cased leads or in "thin leads" of sub-millimetre sizes. While mechanical lead holders cost more initially, they may be the least expensive in the long run where considerable drawing is done.

For your work in beginning drafting, you will need a 2H pencil for general work. You may later want to get a 4H pencil for layout work and an F or HB pencil for lettering and sketching.

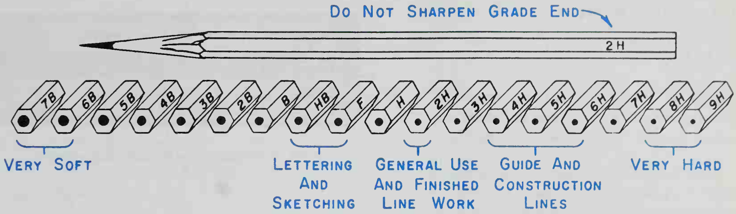


Fig. 1-5. Drawing pencil grades.

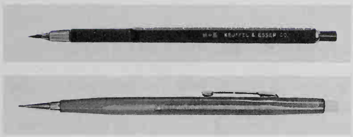


Fig. 1-6. Mechanical lead holders. Top. Standard size leads. Bottom. Sub-millimetre size leads.

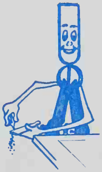
Wood case drawing pencils may be sharpened with a sharp knife or a special drafting pencil sharpener. In the event your school does not have a drafting pencil sharpener, you will most likely be using a knife to sharpen your pencil. This method is discussed here and illustrated in Fig. 1-7.

Sharpen the pencil on the end opposite the grade marking. Remove enough wood to expose approximately 3/8 in. of lead, Fig. 1-7 (a). After the lead has been exposed, shape the lead to a long conical point using a sandpaper pad or file, Fig. 1-7 (b). For final shaping, the point should be finished on a piece of scrap paper, Fig. 1-7 (c). A lead pointer, Fig. 1-8, may also be used to shape the lead. Remove all excess graphite dust from the pencil point by wiping it on a felt pad or soft cloth.

Lead in a mechanical holder is advanced as needed and pointed on a sandpaper pad or in a lead pointer, Fig. 1-8. "Thin leads" never need pointing.

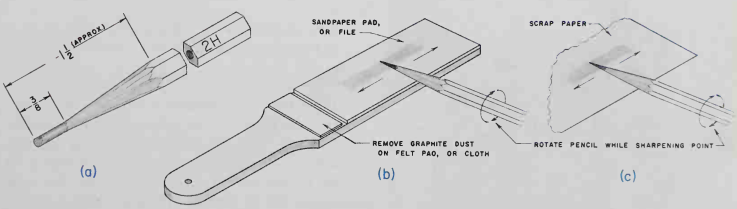
DRAFTING ACTIVITY

Sharpen your 2H drawing pencil.



DRAFTY SAYS:
"Never sharpen your pencil over the drawing board or instruments. Care should also be taken to keep your hands clean in order to produce clean and neat drawings."

Fig. 1-7. Steps in sharpening a drawing pencil.



MEASURING WITH THE FULL–SIZE SCALE

The word "scale" in drafting refers both to the instrument used, Fig. 1-9, and to the size an object is drawn, such as, "full-size" or "1/4 scale."

You will find that, next to the pencil, the scale (ruler to grade school students) is one of the most frequently used tools. Accuracy in measuring is very important, for the work of the drafter affects the work of many others concerned with the object being drawn.

In your beginning plates (drawings), all measurements should be made full-size. With later plates, you will get experience using the 1/2 scale, 1/4 scale, and others familiar to drafters.

Fig. 1-8. Lead for drafting pencils may be pointed by revolving in this lead pointer. (Keuffel & Esser Co.)

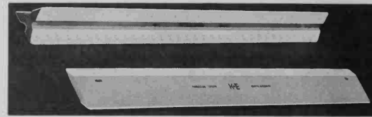


Fig. 1-9. A triangular and a flat scale used in drafting. (Keuffel & Esser Co.)

The best way to learn the proper measuring techniques and to develop accuracy is with a full-size scale. Perhaps you have already had experience with this scale; if so, the following will refresh your memory.

Refer to Fig. 1-10. This is the full size scale on the architect's scale. You will note that the divisions are the same as on the ruler you have used in other classes. Each inch has been sub-divided into sixteenths (the smallest division) with the major markings for 1/8 (2/16), 1/4 (2/8) and 1/2 (2/4) in. By studying Fig. 1-11 closely, you will observe that dimension (a) is equal to 3/16 in., (b) is equal to 7/8 in. and (c) is equal to 1 1/2 in. Try your skill now and complete the reading of the scale.

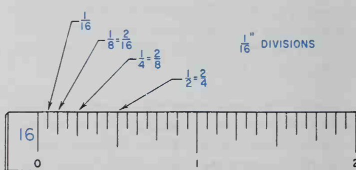


Fig. 1-10. Architect's scale.

DRAFTING ACTIVITY

Read dimensions "d" through "n," Fig. 1-11, and write the dimensions on a separate sheet of paper.

Other than the construction industry, most industries in the United States today are using the decimal inch system of measurement, Fig. 1-12. This system is subdivided into tenths or multiples of 10 such as 50 parts to the inch. Each subdivision on the scale marked "10" is 1/10 or .10 of an inch and each

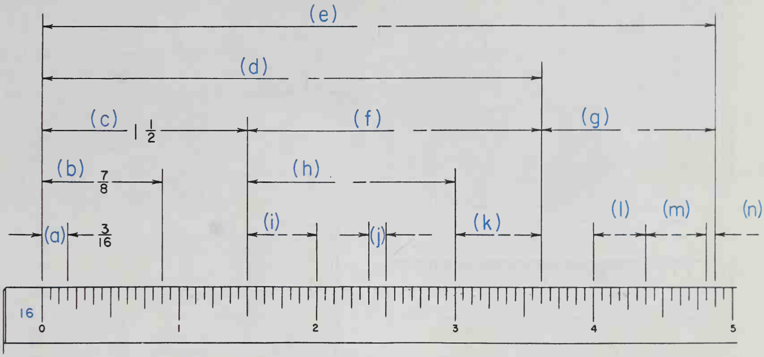


Fig. 1-11. Architect's scale reading problem.

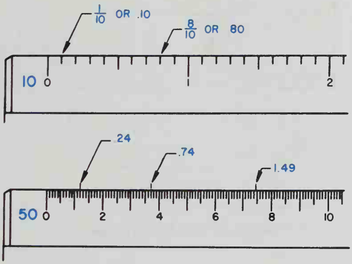


Fig. 1-12. The decimal inch scale or civil engineer's scale.

subdivision on the scale marked "50" is 1/50 or .02 of an inch.

MEASURING WITH METRIC SCALE

The metric scale is a decimal scale with 10 parts or multiples of 10 parts to the unit, Fig. 1-12. A period is used for the decimal point in English speaking countries; most others use a comma. Zero (0) precedes any number smaller than a millimetre, for example 0.14 mm. Refer to Fig. 1-13. This is the full-size metric scale and some measurements are shown.

DRAFTING ACTIVITIES

Read decimal inch dimensions "q" through "v" in Fig. 1-14 and write the dimensions on a sheet of paper.

Read metric dimension "w" through "z" in Fig. 1-15 and write your answers on a sheet of paper.

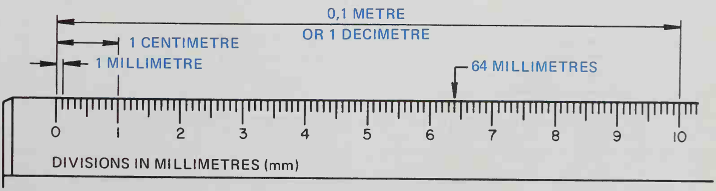


Fig. 1-13. Reading the metric scale.

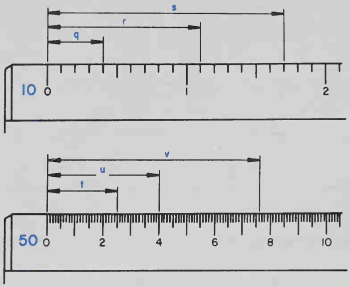


Fig. 1-14. Decimal inch scale reading problem.

Now let's see how well you do with your own scale in the next drafting activity.

DRAFTING ACTIVITY

Measure the length of each line in Fig. 1-16. Write the dimensions on a separate sheet of paper. Your instructor will tell you which scale you are to use.

Your accuracy in measuring can be improved by eyeing the scale directly from above and using a sharp pencil to make a light mark perpendicular to the scale, Fig. 1-17. Accuracy in laying off a series of measurements along a line can be improved by making these measurements without moving the scale, Fig. 1-18.

The scale is a measuring tool and should never be used as a straightedge in drawing a line. Marking on the scale is a grade school trick and is never done by a good drafter. Keep your scale clean so that it can easily be read.

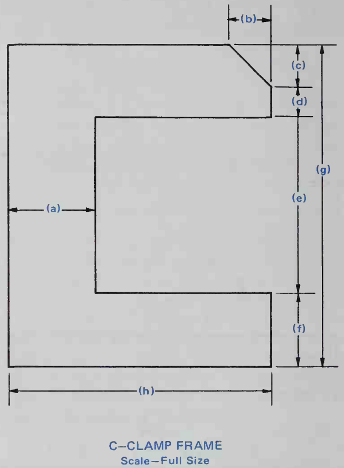


Fig. 1-16. Dimensioning problem.

FASTENING DRAWING PAPER TO BOARD

The drawing paper may be located anywhere on the board as long as it is aligned with the working edge of the board and T-square. However, you will

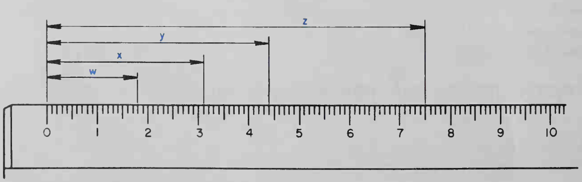
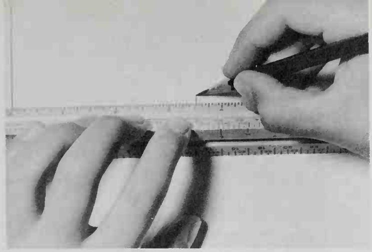


Fig. 1-15. Metric scale reading problem.



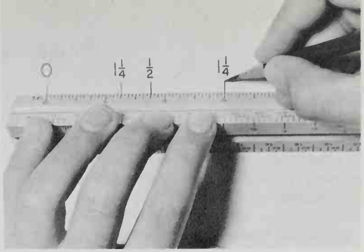


Fig. 1-17. Left. Eye the scale directly from above. Fig. 1-18. Right. Laying off a series of measurements.

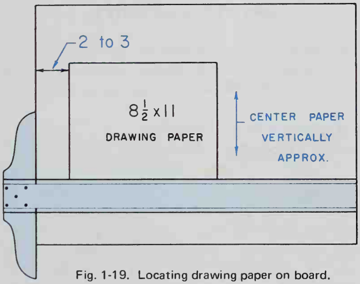


Fig. 1-19. Locating drawing paper on board.

find that you get best results when your paper is located near the working edge of the drawing board and centered vertically, Fig. 1-19.

Position the T-square near the lower part of the drawing board, and place the paper against the

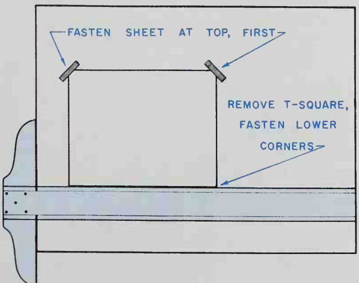


Fig. 1-20. Fastening drawing paper to board.

working edge of the T-square, Fig. 1-20. Adjust the T-square and paper to properly position the paper on the board. Fasten with four pieces of drafting tape.

DRAFTING ACTIVITY

Fasten Plate No. 1 to board.

FORM AND WEIGHT OF LINES

In drafting, lines have a definite form and weight (width). When these are properly constructed, they give meaning and character to your drawing.

Shown in Fig. 1-21 are construction, border and visible lines.

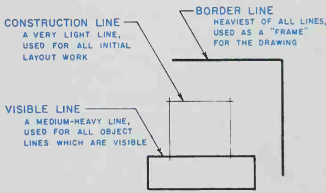


Fig. 1-21. Construction, border and visible lines.

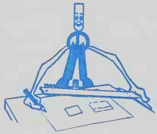
Construction lines are very light lines which can be easily erased. Use these lines to lay out all work. Later, when you are sure of your work, border lines and visible lines can be darkened to their proper weight.

A complete alphabet of lines used in drafting is shown on page 124.

BORDER AND TITLE BLOCK

A border line is usually drawn around a sheet to serve as a "frame" for the drawing. The border should be drawn very lightly at first and darkened when the plate is completed.

In addition to the border a title block is included on all plates. Architects, drafters in industry, and others making drawings include information here to identify and supplement the drawing. Such things as the name of the industry, object drawn, scale of drawing, drafter's name, checker or supervisor, and date, are included. For your drawings you will want to leave space for the name of your school, title of plate (name of object drawn), scale, date, your name and plate number. Refer to page 123 for suggested title block layouts.



DRAFTY SAYS:
"In layout work use light construction lines."

DRAFTING ACTIVITY

Plate No. 1

Lay out "Plan A" border and title block. Refer to page 123. Unless otherwise directed, all of your plates will be laid out with the "Plan A" border and title block.

Many of the drawing problems in this text will require that your plate be divided into four equal sections, Fig. 1-22 (c). To divide your plate in this manner, follow this procedure:

1. Lay the scale across your plate with the zero of the scale on the line above the title block with a number easily divisible by 2, such as 12, on the top border line, Fig. 1-22 (a).
2. At the center point, 6 in., mark a short dash parallel to the horizontal border lines. This is the location for the horizontal dividing line.
3. Follow the same procedure for locating the vertical dividing line, Fig. 1-22 (b).
4. Draw light lines through these points to divide plate into four equal sections, Fig. 1-22 (c).

DRAFTING ACTIVITY

Plate No. 1

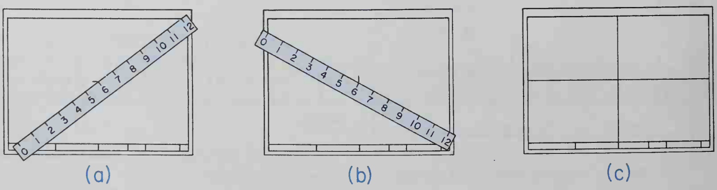
Divide plate into 4 equal sections.

ERASING PENCIL MARKS AND CLEANING DRAWINGS

Even the best drafters find it necessary to erase at times, and when they do, they use the correct eraser and technique for the job. You should have either a soft red rubber or white vinyl eraser for removing lines and other pencil marks, and for cleaning overall areas of the drawing, Fig. 1-23. An ink eraser which contains abrasives should never be used since it scratches the surface of the drawing paper and produces "ghosting" on reproductions.

Fig. 1-23. Erasers used in drawing.

Fig. 1-22. Dividing plate into four equal parts.



When erasing is necessary, follow this procedure:

1. Clean the eraser by rubbing it on scrap paper before using it on your drawing.
2. With your free hand, hold the drawing firm to avoid wrinkling.
3. If necessary, to protect surrounding area, use an erasing shield, Fig. 1-24.
4. Move eraser lightly back and forth until line disappears.
5. Clean plate with soft eraser before final finishing of lines.
6. Dust surface of drawing with brush or cloth after erasing.

The bad effects of erasures can be avoided by drawing all lines in lightly. Remember, erasing will not remove deep pencil grooves in your drawing paper.

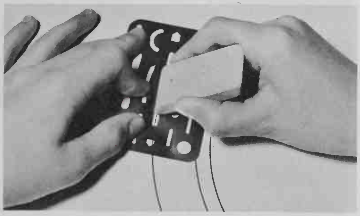


Fig. 1-24. Erasing shield in use.

DRAWING HORIZONTAL LINES

Horizontal lines are drawn from left to right, with the T-square held firmly against the left edge of the drawing board. (Left handers should reverse this procedure.) After the T-square is in position for the line to be drawn, move the left hand to a position on the T-square blade to prevent the T-square from slipping. The pencil is slanted at an angle of 60 deg. to the right, Fig. 1-25, the direction the line is to be drawn. Let the little finger slide along on the T-square as you rotate the pencil between the thumb and forefinger. Rotating the pencil will help you to keep the point sharp, and get a uniform line weight (width).

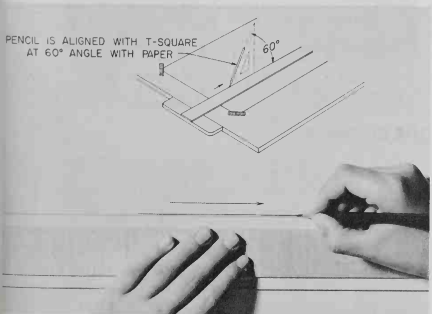
DRAWING VERTICAL LINES

Vertical lines are drawn toward the top of the board along the vertical edge of either the 30-60 deg. triangle or the 45 deg. triangle. The triangle is held securely against the T-square with the left hand, Fig. 1-26. The pencil is again slanted at a 60 deg. angle in the direction in which the line is being drawn and rotated slowly.

DRAFTING ACTIVITY

Plate No. 1

1. Section A. Draw a series of horizontal lines as shown in Fig. 1-27.



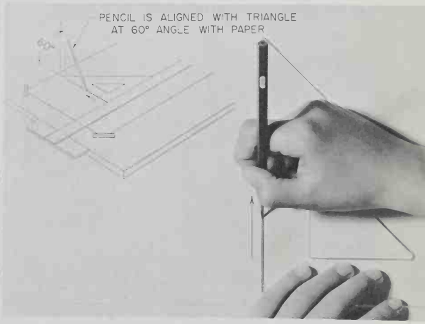


Fig. 1-25. Left. Drawing a horizontal line. Fig. 1-26. Right. Drawing a vertical line.

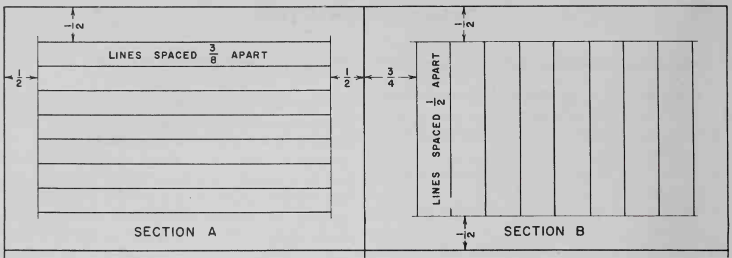


Fig. 1-27. Layout for Sections A and B, Plate No. 1.

2. Section B. Draw a series of vertical lines as shown in Fig. 1-27.
3. These lines should be drawn lightly at first. When your work has been checked by your instructor, the lines can be darkened to the weight of visible lines.

DRAWING INCLINED LINES

An inclined line is any straight line other than a horizontal or vertical line. It is usually drawn by using one or two triangles in combination with a T-square. By using the triangles separately, or by combining them as shown in Fig. 1-28, any 15 deg. angle from the horizontal or vertical can be drawn. Note the directions in which the lines are drawn as indicated by the arrows, Fig. 1-28.

The triangles can also be used as a straightedge to join two points with a straight line, Fig. 1-29.

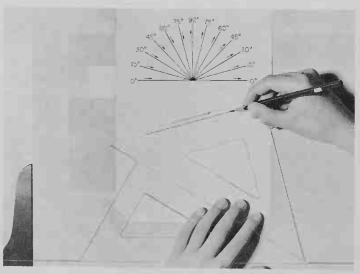


Fig. 1-28. Combining triangles to draw 15 deg. and 75 deg. lines with the horizontal.

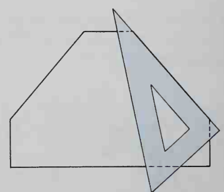


Fig. 1-29. Using the triangle as a straightedge.

DRAFTING ACTIVITY

Plate No. 1

1. Draw inclined lines in sections C and D, as shown in Fig. 1-30.
2. Darken these lines and the border lines to the proper weight.
3. Sign your name in the lower right hand corner of Plate No. 1 and hand to your instructor. (Lettering of a title block will come later.)

THE COMPASS

You have likely used the pencil compass to draw circles in some of your math classes. This same compass could be used in beginning drafting, but compasses which can be adjusted more accurately are often needed. Two types of compasses used in drafting are the BOW PENCIL with the fine adjusting screw, Fig. 1-31 (a), and the friction-joint compass usually referred to simply as the COMPASS, Fig. 1-31 (b). When the radius of the arc or circle is 1 in. or less, use the bow pencil. For an arc or circle whose radius exceeds 1 in., use compass, or a large bow

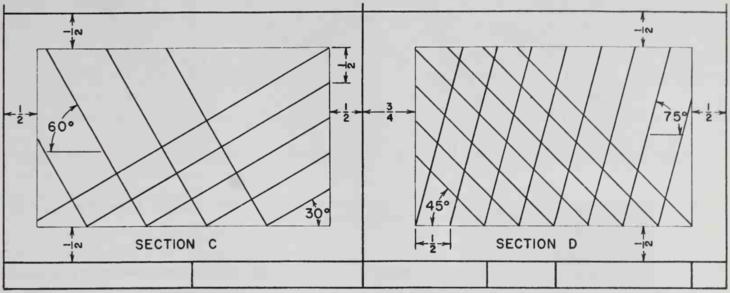


Fig. 1-30. Layout for Sections C and D of Plate No. 1.

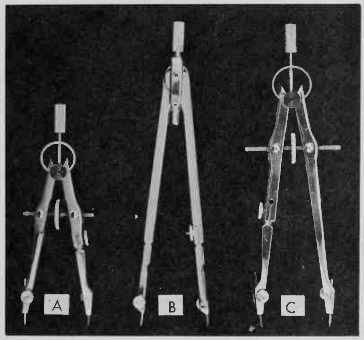
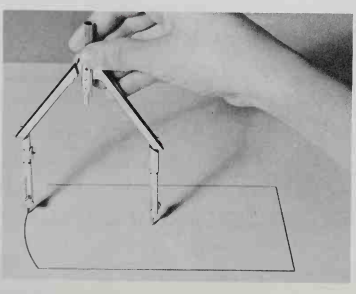


Fig. 1-31. Above. The bow pencil, friction-joint compass, and the large bow pencil. Fig. 1-32. Below. Using compass with the knees bent.



pencil, Fig. 1-31 (c). For an arc or circle with radius greater than 2 in., the legs of the compass should be bent at the knees and adjusted to meet the paper in a vertical position, Fig. 1-32. Insert the lengthening bar in the compass for a radius greater than 5 in.

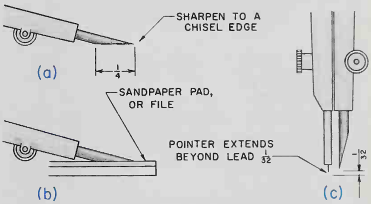


Fig. 1-33. Compass lead has a chisel edge.

SHARPENING COMPASS LEAD

The lead in your compass should be one grade softer than the lead in the drafting pencil you are using for line work. Usually, an F or H grade will give satisfactory results.

Your drafting pencil lead is sharpened to a conical point, but the compass lead is sharpened more like a chisel edge, Fig. 1-33 (a). Adjust the lead in the compass so that approximately 3/8 in. extends from the compass leg. Sharpen the lead (one side only) on a sandpaper pad or file to form a face of about 1/4 in. in length, Fig. 1-33 (b). Clean the graphite dust from

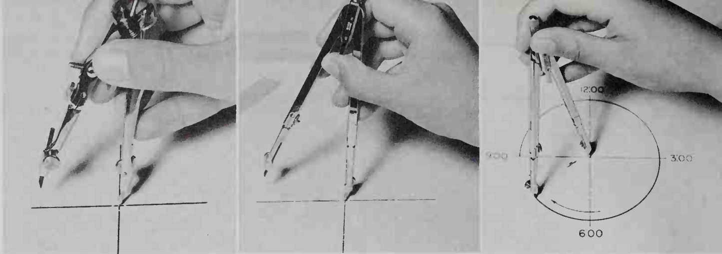


Fig. 1-34. Left. Adjusting the bow pencil. Fig. 1-35. Center. Adjusting the compass. Fig. 1-36. Right. Drawing a circle with the compass.

the lead with a soft cloth. Adjust the compass needle in the other leg of the compass so that the end containing the point with the shoulder extends beyond the lead approximately 1/32 in., Fig. 1-33 (c).

DRAWING ARCS AND CIRCLES

The bow pencil is adjusted by twisting the adjusting screw between the thumb and the forefinger, see Fig. 1-34. The compass is adjusted by spreading the legs with the thumb and second finger, see Fig. 1-35.

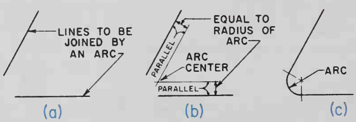


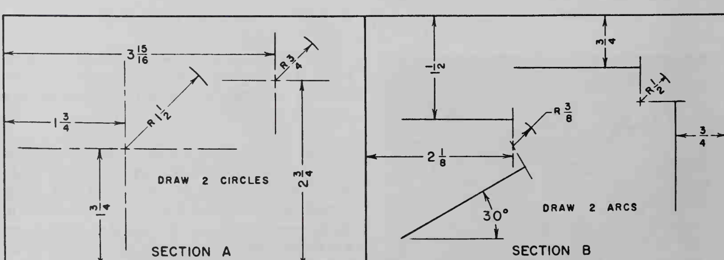
Fig. 1-37. Joining two lines with an arc.

To set the compass, measure off the radius (R) — 1/2 of the diameter (ϕ) — on a scrap piece of paper, or lightly on your drawing, and adjust the compass accordingly. Test the setting on scrap paper; check your measurements carefully.

To draw a circle, hold the compass in one hand and start at the "9 o'clock" position, Fig. 1-36, lean the compass slightly forward and revolve in a clockwise direction by rotating the handle between the thumb and forefinger. (Left handers, counterclockwise, starting at 3 o'clock.) Draw circle in lightly until you are sure it is correct.

Refer to Fig. 1-37 and note that an arc is just a part of a circle. Two lines to be joined by an arc are shown in Fig. 1-37 (a). The center of the arc is located by constructing lines parallel to the lines to be joined, and at a distance equal to the radius of the arc, Fig. 1-37 (b). Set your compass, and join the two lines with an arc. Fig. 1-37 (c). Draw the arc lightly until you are sure it is correct.

Fig. 1-38. Layout for Sections A and B, Plate No. 2.



DRAFTING ACTIVITY

Plate No. 2

1. Draw arcs and circles in section A and B, as required in Fig. 1-38.
2. Sign your name on your plate.

Darken all arcs and circles just before straight lines are to be finished. Avoid making a large hole in your paper with the compass point.

Arcs and circles may also be drawn with the aid of a circle template, Fig. 1-39. These templates come in various sizes and are used by industry to speed the drafting process. The template is placed directly over center lines and the required arc or circle is drawn.

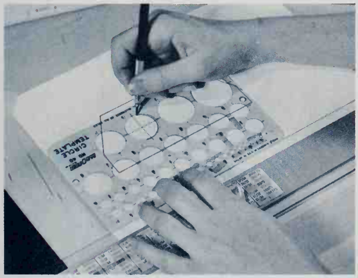


Fig. 1-39. Drawing a circle with the aid of a circle template.

THE DIVIDERS

Two types of dividers used extensively by drafters are similar to the friction-joint compass and the bow pencil; however, the dividers are equipped with a second steel point rather than a pencil, Fig. 1-40. Dividers are used in transferring distances, Fig. 1-41, and in dividing distances equally, Fig. 1-42.

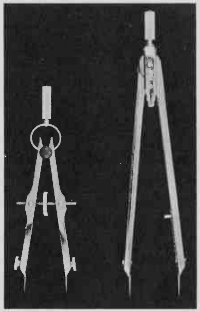


Fig. 1-40. Two types of dividers.

Avoid puncturing the paper with the divider points. Make light dents with the points and, if necessary, mark the place immediately with a sharp pencil.

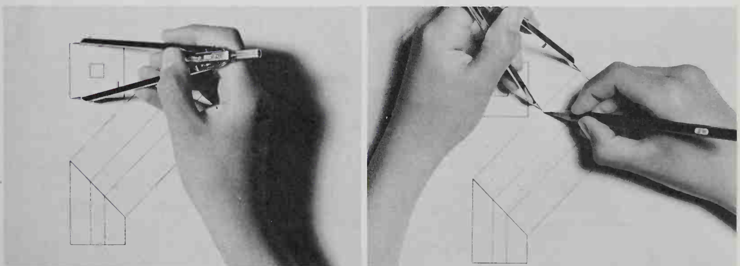
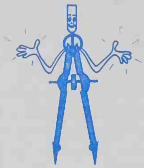


Fig. 1-41. Transferring distances with dividers.



DRAFTY SAYS:

"Keep your hands clean."

DRAFTING ACTIVITY

Plate No. 2

Divide the lines in section C as required in Fig. 1-43.

GEOMETRICAL METHOD OF DIVIDING A LINE OR SPACE INTO EQUAL PARTS

There are several ways of dividing a line or space into equal parts. One method, using the dividers, was shown in Fig. 1-42. Another method would be to divide the line mathematically. Still another method which you will find useful in drafting, as well as in your shopwork, is the geometrical method. You have been using this method in dividing your plates into four sections. Now let's see how it works for dividing a line or piece of lumber. The procedure is as follows:

1. Line AB = 6 7/16 in. to be divided into five equal parts, Fig. 1-44 (a).

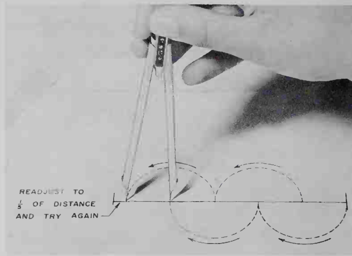


Fig. 1-42. Dividing distances equally with dividers.

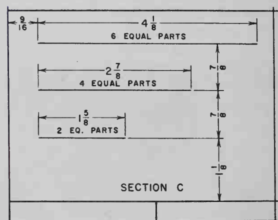
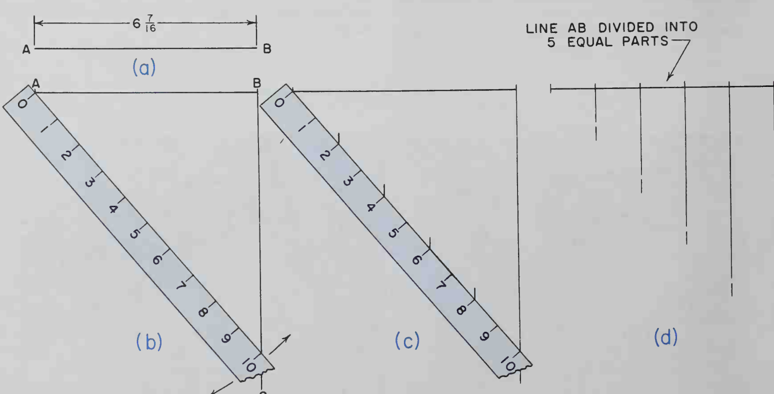


Fig. 1-43. Layout for Section C of Plate No. 2.

Fig. 1-44. Geometrical method of dividing a line.



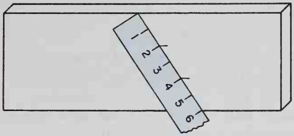


Fig. 1-45. Dividing board into equal parts geometrically.

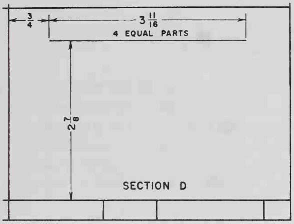


Fig. 1-46. Layout for Section D, Plate No. 2.

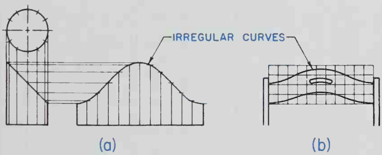


Fig. 1-47. Irregular curves.

Fig. 1-48. These instruments are called French curves or irregular curves. (Keuffel & Esser Co.)

2. Drop a vertical (perpendicular) line BC down from B, Fig. 1-44 (b).
3. With the zero on the scale at point A, rotate the scale until a number easily divisible by five, such as 10, crosses line BC, Fig. 1-44 (b).
4. Mark off the 5 divisions with short dashes parallel to line BC, Fig. 1-44 (c).

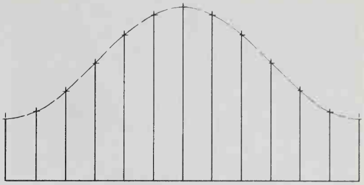


Fig. 1-49. Freehand line sketched through points on an irregular curve.

5. Project vertical lines through these points to line AB, Fig. 1-44 (d).

This same method may be used in dividing a board into equal parts, Fig. 1-45.

Try your skill at dividing a line by the geometrical method in the next drafting activity.

DRAFTING ACTIVITY

Plate No. 2

1. Use section D and divide the line as shown in Fig. 1-46.
2. Date the plate.

In addition to your plate layouts, you will use this skill in the solution of some problems in the shop.

DRAWING IRREGULAR CURVES

The drafter is frequently required to draw curves which are not circles or arcs. These are called irregular curves, Fig. 1-47. They should be drawn with smoothness and accuracy. To achieve these qualities, they may be drawn freehand, or with a FRENCH CURVE, or IRREGULAR CURVE, Fig. 1-48.

The procedure for drawing an irregular curve is as follows:

1. Points are established either by projection as in sheetmetal pattern development, Fig. 1-47 (a), or by the squares method of enlarging a design, Fig. 1-47 (b).
2. Sketch a very light freehand curve through these points, Fig. 1-49. (If curve is to be completed by the freehand method, darken the line by letting the eye lead the pencil over the light construction lines. If French curve is to be used, omit freehand darkening of line, and continue with Step 3.)

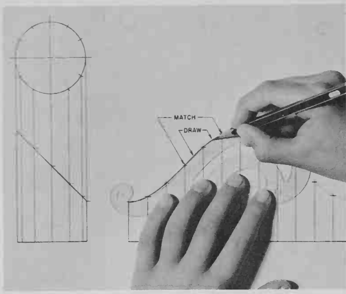


Fig. 1-50. Using the French curve to draw an irregular curve.

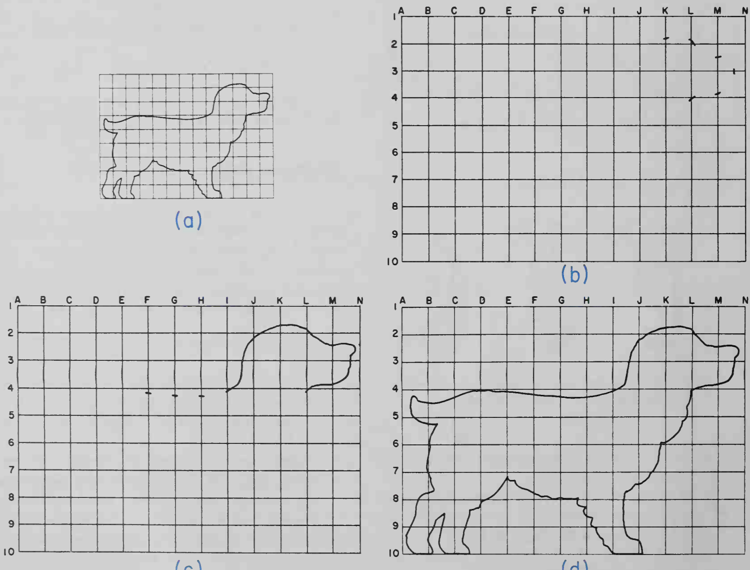
3. Match this curve with the French curve. Try to cover three or more points at each setting, Fig. 1-50.
4. Draw only part of the curve at each setting. Stop before reaching the point of separation, Fig. 1-50.
5. Make each new setting of the curve flow out of the previous setting, Fig. 1-50.

You will get an opportunity to practice this skill in the following section.

ENLARGING A PATTERN BY SQUARES METHOD

Securing a good design for the projects you want to build, either in the school shop or at home, is a real challenge. Such designs can be purchased, created by yourself, or enlarged from small drawings or photographs. You may have occasion to use each of these. Let's consider the method of enlarging by squares, Fig. 1-51.

Fig. 1-51. Enlarging a pattern by the squares method.



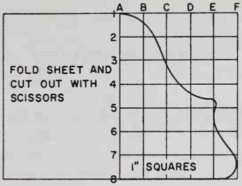
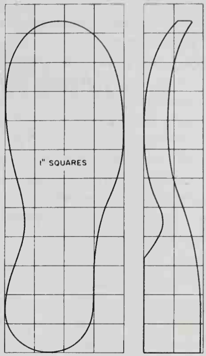
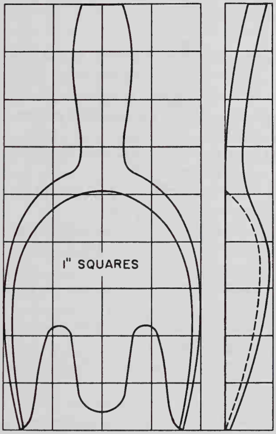


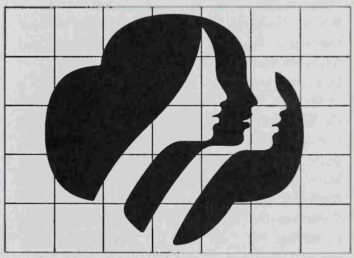
Fig. 1-52. Draw only one half of designs which are symmetrical.



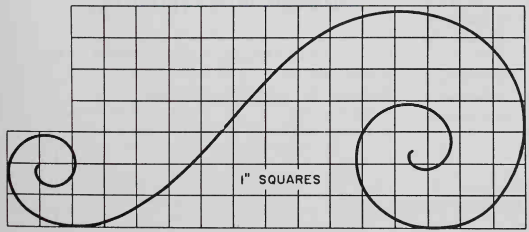
SHOWER SHOES



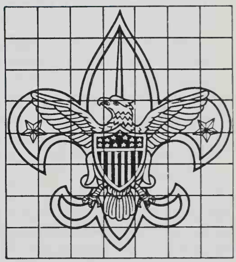
SPAGHETTI SERVERS



GIRL SCOUTS



SCROLL DESIGN



BOY SCOUT EMBLEM

Fig. 1-53. Designs to be enlarged.

You may have observed drawings or photographs of designs for projects in magazines or catalogs, and wished that you had a way of enlarging these. Actually, this can be done quite easily. To enlarge a design, follow this procedure:

1. Lay off squares on the design, Fig. 1-51 (a), or on a piece of transparent paper and place it over the design. On many designs found in books and magazines, squares are already drawn and the size of the enlarged squares are indicated, as in Fig. 1-52. You can control the size of the enlargement by the size of the squares:

Squares on Design	To Enlarge	Squares on Enlargement
1/4 in.	Two times	1/2 in.
1/4 in.	Three times	3/4 in.
1/4 in.	Four times	1 in.

2. Lay off squares of proper size for enlargement on a plain sheet of paper, as shown in Fig. 1-51 (b). (Use wrapping paper for larger designs.)
3. For convenience in transferring points, number the horizontal lines from top to bottom, and letter the vertical lines from left to right.
4. Start at a prominent point, such as a corner or a projection, on the design and mark the points on the enlarged pattern where the design crosses the numbered and lettered lines. Check your starting point carefully for location, Fig. 1-51 (b).
5. Mark a few more points and then join them freehand, Fig. 1-51 (c).
6. Complete the location of points and freehand sketching, Fig. 1-51 (d). The French curve may be used on some designs to get a smooth curve.
7. To save time in transferring designs which are symmetrical (identical on both sides), draw only one half, fold the paper and transfer the design to the other half by rubbing the back side of the original line with a coin, or cut it out with the scissors, Fig. 1-52.
8. Your pattern is now ready for use. Cut it out and trace it on your material. Transfer it by use of carbon paper; or by a tracer tool if your material is leather.

DRAFTING ACTIVITY

Plate No. 3

Select a design from those shown in Fig. 1-53, or from another book or a magazine, and enlarge by the squares method. Use drawing paper or wrapping paper of appropriate size for the enlargement.

QUIZ – UNIT 1

Write answers on separate sheet of paper. Do not write in book.

1. Drafting is the "language of industry." Explain what is meant by this statement.
2. What changes are necessary in drawings for them to be used in a country where another language is spoken?
3. In what ways are you likely to use the skills you acquire in drafting?
4. Discuss some things you can do to keep your drawings clean and neat.
5. In drawing horizontal, vertical and inclined lines, why is the pencil slanted in the direction the line is to be drawn?
6. Explain why ink erasers should not be used on drawings.
7. Why is it poor practice to use the scale as a straight edge?
8. What are the requirements of a good drawing board?
9. The squares on a design are 1/4 in. How large should the square in the enlargement be in order to enlarge this design five times?
10. What is the heaviest line used in drafting?

NEW WORDS FOR YOU TO USE

Diameter (di-am'e-ter)
Graphic (graf'ik)
Horizontal (hor-i-zon'tal)
Metric (met'rik)
Multiview (mul'ti-vu)
Projection (pro-jek shun)
Radius (ra'di-us)
Scale (skal)
Technician (tek-nish'an)
Vertical (vur'ti-kal)

Unit 2

FREEHAND SKETCHING

After studying this unit, you will know:
1. What is freehand sketching.
2. Where freehand sketching is used.
3. What skills are required to make good freehand sketches.

Freehand sketching is the technique of making a drawing without the use of instruments. It is used frequently by the drafter as the first step in the making of an instrument drawing and is the principal means by which the skilled worker, the technician, or the engineer presents ideas to others. You, too, will use sketching in your shopwork at school and at home.

Because sketching is done freehand, you will need only a small amount of equipment: an F or HB pencil, drafting erasers and paper (regular drafting paper, cross sectioned paper, or unruled notebook paper). There are certain skills that must be learned in order to produce good sketches. These skills are the sketching of horizontal, vertical, inclined lines, arcs and circles. Proportion must also be considered.

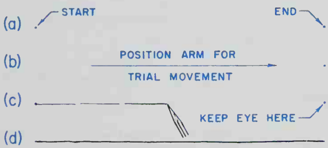


Fig. 2-1. Steps in sketching horizontal lines.

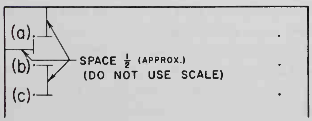


Fig. 2-2. Layout for section A, Plate No. 4.

SKETCHING HORIZONTAL LINES

Horizontal lines are sketched in the following manner:

1. Locate the starting and ending points of the line, Fig. 2-1 (a).
2. Make several trial movements to position arm, take short strokes from left to right (left handers right to left) keeping eye on end point, Fig. 2-1 (b).
3. Sketch short light lines at first, Fig. 2-1 (c) (no fuzzy scratches). This will help you control the direction of the line. The line appears as broken sections in the construction stage.
4. Darken the line using one continuous stroke, Fig. 2-1 (d). To do this, let your eyes lead your pencil along the light construction line.

DRAFTING ACTIVITY

Plate No. 4

1. Lay out border, title block and divide plate into four sections with instruments.
2. Sign your name on your plate.
3. In section A, sketch three horizontal lines lightly between the points, as shown in Fig. 2-2. Do not darken these lines.

Are the lines straight? Do they end at the desired points? Were they constructed in short sections?

In the drafting activity which follows, you will sketch additional horizontal lines in the remaining space of Section A. Remember, this is freehand sketching – no scales allowed. Follow the same procedure as for lines a, b and c; then darken these lines forming straight continuous lines. Your lines should

be uniform in weight (width and darkness). It is not expected that freehand lines will be as straight as mechanical lines, but a good drafter will strive for neatness and accuracy in sketching, too.

DRAFTING ACTIVITY

Plate No. 4

In section A, sketch additional horizontal lines and darken.

Are these lines straight? Are they uniform in weight?

SKETCHING VERTICAL LINES

The sketching of vertical lines is quite similar to the sketching of horizontal lines — only the direction of arm movement changes to a downward movement toward the body.

The procedure is as follows:

1. Locate the starting and ending points, Fig. 2-3 (a).
2. Without marking your paper, make trial arm movements between top and bottom points to position arm (it will help to line the points up by sight), Fig. 2-3 (b). Use a pulling arm and finger movement in sketching.
3. Sketch short, light lines at first, Fig. 2-3 (c), and keep your eye on the point at which the line is to end.
4. Darken the line to form one continuous line of uniform weight, Fig. 2-3 (d). To do this, let your eye lead your pencil along the light construction line.

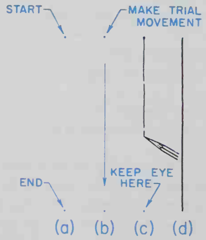


Fig. 2-3. Steps in sketching vertical lines.

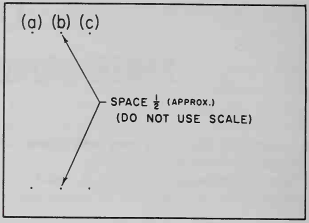


Fig. 2-4. Layout for Section B, Plate No. 4.

DRAFTING ACTIVITY

Plate No. 4

1. In section B, sketch vertical lines between the three sets of points: a, b and c, as shown in Fig. 2-4.
2. Sketch the lines lightly.

Check your lines for straightness. Are the short strokes of the construction lines observable? Try to improve your skill in sketching vertical lines by sketching the lines in the next drafting activity.

DRAFTING ACTIVITY

Plate No. 4

1. Locate additional sets of points for vertical lines in section B by approximating spacing similar to lines a, b and c.
2. Follow the same procedure as for lines a, b and c; darken these lines.

Are your lines straight? Are they uniform in weight?

Vertical lines may be sketched as horizontal lines when it is convenient to rotate the paper.

SKETCHING INCLINED LINES

As indicated in Unit 1, inclined lines include all straight lines other than horizontal and vertical. If their position is more horizontal than vertical, they should be sketched as horizontal lines — from left to right. If their position is more nearly vertical, sketch them as vertical lines — from top downward. When possible, the paper may be rotated for convenience in sketching.

DRAFTING ACTIVITY

Plate No. 4

1. In section C, follow the procedure for sketching horizontal or vertical lines, and sketch inclined lines between the three sets of points (a-a', b-b', c-c') as shown in Fig. 2-5.
2. Sketch the lines lightly.

Check your lines for straightness and uniformity of line weight.

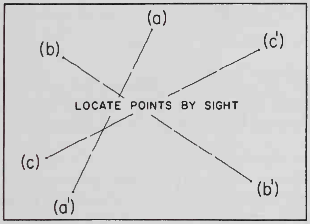


Fig. 2-5. Layout for Section C, Plate No. 4.

DRAFTING ACTIVITY

Plate No. 4

1. Lay out additional sets of points for inclined lines in section D.
2. Sketch lines between these points and darken.
3. Date your plate.

SKETCHING ARCS AND CIRCLES

The ability to sketch arcs and circles is essential for the drafter doing freehand sketching. You, too, will find it to your advantage to develop this skill. Arcs and circles may be neatly sketched by using the following procedure:

1. Sketch center lines of the arcs or circles, Fig. 2-6 (a).
2. Locate points in the radius (use scrap of paper or pencil as gage), Fig. 2-6 (b).
3. Make trial movements between points using a radial arm and wrist movement and include at least three points in each movement, Fig. 2-6 (c).
4. Sketch light arc in a clockwise or downward movement, depending on position (paper may be rotated for convenience), Fig. 1-6 (d). Keep eye

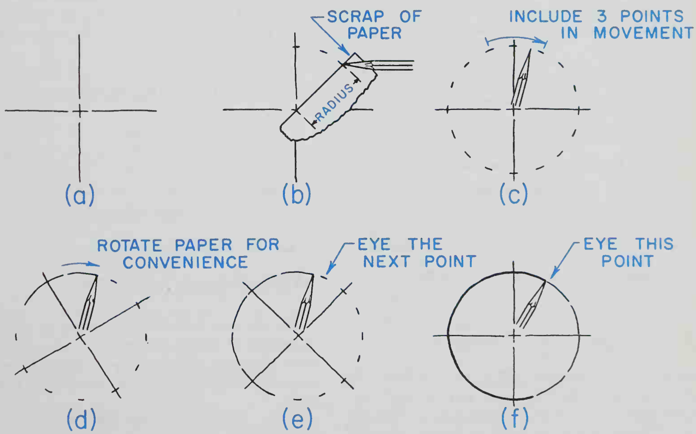
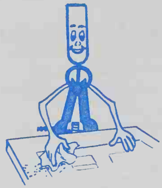


Fig. 2-6. Steps in sketching circles.



DRAFTY SAYS: "Remove erasure dust from drawing with brush or soft cloth."

on the next point, Fig. 2-6 (e).

5. Sketch complete arc or circle lightly.
6. Darken arc or circle with uniform dense line, let the eye lead the pencil along the light construction line, Fig. 2-6 (f).

DRAFTING ACTIVITY

Plate No. 5

1. Sketch border, title block, and lines to divide plate into four sections.
2. Write your name on your plate.
3. In section A, sketch circles around points "a" and "b" as shown in Fig. 2-7.
4. Sketch circle "a" and leave light construction lines.
5. Sketch circle "b" and darken.

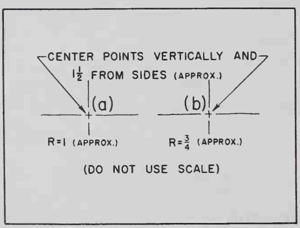


Fig. 2-7. Layout for section A, Plate No. 5.

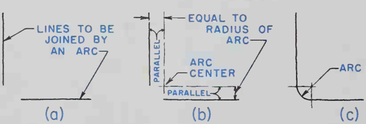


Fig. 2-8. Steps in sketching arcs.

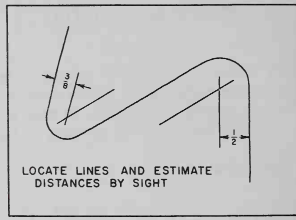


Fig. 2-9. Layout for section B, Plate No. 5.

Are the circles true and uniform around their centers? Does circle "a" show light construction lines in sections? Is circle "b" uniform in line weight?

In many sketching problems, it is necessary to sketch arcs at corners or between two lines. Let's see if you can apply what you have learned in sketching circles to sketching arcs. Two lines to be joined by an arc are shown in Fig. 2-8 (a). You remember that the center of an arc is located by sketching construction lines parallel to the lines to be joined with the arc, Fig. 2-8 (b). The radius points may be laid out with a scrap of paper and sketched in the same manner as for a circle, Fig. 2-8 (c).

DRAFTING ACTIVITY

Plate No. 5

1. In section B, sketch two arcs connecting lines shown in Fig. 2-9.
2. Show construction lines in locating centers of arcs and darken arcs.

Are the arcs ture? Is the line weight uniform?

PROPORTION IN SKETCHING

So far, you have learned something about the techniques of sketching straight lines, arcs and circles. With additional experience, you should be able to execute these procedures with considerable ease and skill.

There is another important element, however, in sketching objects consisting of straight lines, arcs and

circles; that is, PROPORTION. If a square is to look like a square, it must have equal, or nearly equal, sides. If a sketch of a table is to resemble a table and have value, then the height and width of the sketch must be proportional.

Remember the object of freehand sketching is to develop skill in drafting without the use of instruments; therefore, you must develop the technique of getting proportion in your sketches without the use of a scale. (Many drafters carry a small pocket rule which they use as a straightedge and for measuring purposes in freehand sketching, but they also have the ability to sketch and to gage proportion without its use.)

Your pencil may be used as a gage in checking the sides of a square or other geometric form. A scrap of paper may also be used. There are other means of gaging proportion which your instructor may want to show you if time permits.

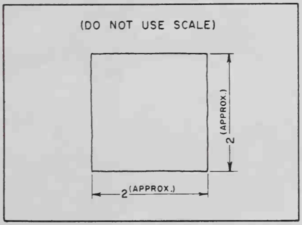


Fig. 2-10. Layout for section C, Plate No. 5.

DRAFTING ACTIVITY

Plate No. 5

1. In section C, sketch a square having sides of approximately 2 in. in length, Fig. 2-10.
2. Estimate distances and spacing by sight. Do not use a scale.

Are the sides equal? Are the corners square?

DRAFTING ACTIVITY

Plate No. 5

1. In section D, sketch a right triangle (one with a 90 deg. angle) having a base of approximately 1 1/2 in. in length, Fig. 2-11.
2. Estimate distances and spacing by sight. Do not use a scale.

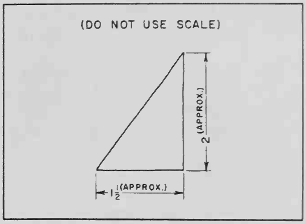


Fig. 2-11. Layout for section D, Plate No. 5.

AIDS IN SKETCHING

In many cases you will be making freehand sketches without the use of instruments. However, when aids are available they can be used to improve the sketching technique.

1. When sketching a straight line parallel to the edge of the paper or board, use the edge for a guide and your finger as a gage.
2. When sketching a straight line, a folded piece of paper makes a good straightedge.
3. When sketching a 90 deg. angle, a piece of paper may be folded across the straightedge to form a right angle.
4. When sketching a 45 deg. angle, a right angle corner can be folded diagonally.
5. A scrap piece of paper is helpful when sketching equal distances, such as radius points for a circle. Your pencil with its lettering also makes a good measuring device.
6. A small 6 in. pocket rule comes in handy, both for straightedge work and for measuring.
7. A string-and-pencil compass has been used for a long time to make arcs and circles.

These are aids to freehand sketching and should not be confused with instrument drafting. You should first learn the freehand techniques discussed in this unit without using the above aids so that you will be prepared when aids are not available. Later, when quality and speed can be improved with the use of

aids and they are available, they may be used. In the next unit on working drawings, you will begin to use your sketching ability.

QUIZ – UNIT 2

1. What is the value of sketching to the drafter?
2. What equipment is needed to do freehand sketching?
3. How can you improve the straightness and direction of horizontal, vertical and inclined lines in freehand sketching?
4. What is proportion in sketching? Of what importance is it?
5. Suggest some uses which you can make of the freehand sketching technique.
6. What are some aids which may be used in sketching? When should you make use of these?

NEW WORDS FOR YOU TO USE

1. Approximate (a-prok'si-mit)
2. Clockwise (klok'wiz)
3. Gage (gaj)
4. Parallel (par'a-lel)
5. Proportion (pro-por'shun)
6. Uniform (u'ni-form)

An industrial design-drafting room.
(Bendix Corp.)

Fig. 3-1. Preparing a working drawing in industry. (McDonnell-Douglas Corp.)

Unit 3

WORKING DRAWINGS—DRAFTING CAREERS

After studying this unit, you will know:

1. What is a working drawing.

2. What is orthographic projection.

3. How are views selected.

Of all the types of drawings made by drafters, the WORKING DRAWING is the one most frequently used. As the name implies, it is the drawing from which craftworkers get the information they need in the construction, installation, assembly or servicing of an object. See Fig. 3-1. They readily see the shape, size and details of the object, IF they can read the "language of industry."

In this unit you will begin making working drawings of objects. First, let's see how the different views of a working drawing are obtained.

ORTHOGRAPHIC PROJECTION

Let's take a simple object and imagine that it is placed in a hinged glass box (projection box), Fig. 3-2

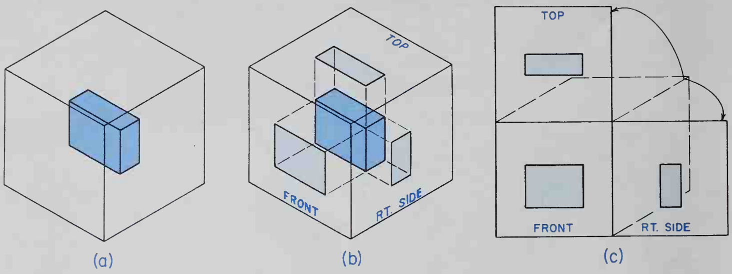


Fig. 3-2. The "glass" projection box in use.

(a). Imagine, also, that the views of the object are projected to the front, top and right sides of the glass box (planes of projection), Fig. 3-2 (b). Now fold the top and right-side planes in line with the front plane, Fig. 3-2 (c). This type of projection is called ORTHOGRAPHIC PROJECTION which means perpendicular or right-angle projection. It also means that the top view is always directly above the front view, and the right-side view (sometimes called right-end view) is always to the right of the front view and in line with it.

As many as six views may be obtained in this manner (the others would be leftside, rear and bottom views). However, you should draw only those views that are necessary to describe the object clearly.

If you were going to lay out a tennis court, Fig. 3-3, one view would be sufficient. One view is all that is needed to describe certain objects to be made in the shop such as a template (pattern), Fig. 3-4 (a), or cutting board, Fig. 3-4 (b), where the thickness of the material can be indicated in a note.

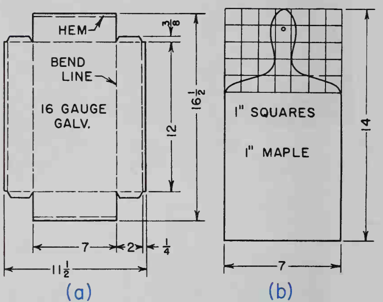


Fig. 3-4. One-view shop drawings.

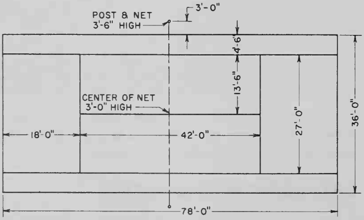


Fig. 3-3. One view of a tennis court is sufficient.

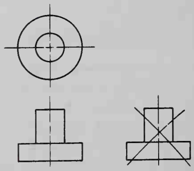


Fig. 3-5. Draw only the necessary views.

For most cylindrical objects, two views are sufficient. In Fig. 3-5, the right-side view is identical to the front view. Again, show only the number of views necessary to clearly describe the object – no more. When two or more views are shown, the drawing is sometimes referred to as a MULTIVIEW DRAWING.

Nearly all of the projects which you will make in the school shop or at home will require three views to describe adequately the details of their construction.

Two objects are shown in Fig. 3-6, to help you visualize the way in which multiviews are obtained. When you have learned this technique, you are well on your way to understanding multiview drawing. Study the objects and views carefully and make certain NOW that you understand the projection techniques.

Let's see how well you have learned this technique. Fig. 3-7 shows four more blocks. These blocks are quite different in their pictorial views. One block has been drawn correctly in the multiview drawing in Fig. 3-7. If multiview drawings were made of the other three blocks, which of their views would be exactly like those shown?

Study the pictorial views carefully and, on a separate sheet of paper, draw a form similar to the

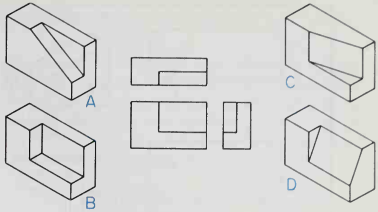


Fig. 3-7. Which block has been drawn correctly in the multiview?

one below. Indicate with check marks (√) the views which are correct for each block and with zeros (0) the views which are incorrect.

	Views		
	Top	Front	Right Side
Block A	____	____	____
Block B	____	____	____
Block C	____	____	____
Block D	____	____	____

If you can distinguish between these objects in their multiview projections, you are making real progress. Good luck.

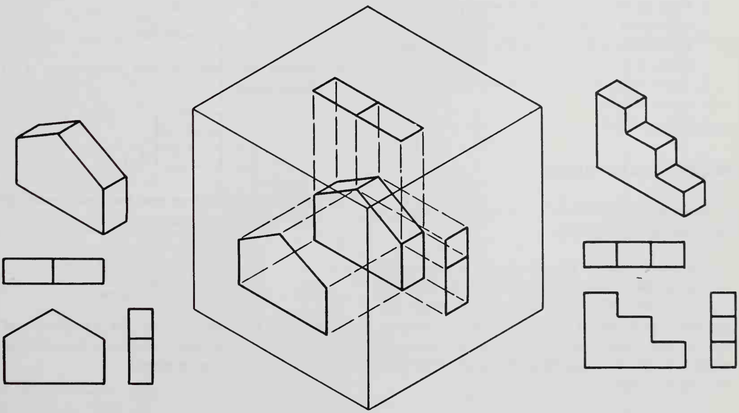


Fig. 3-6. Orthographic projection.

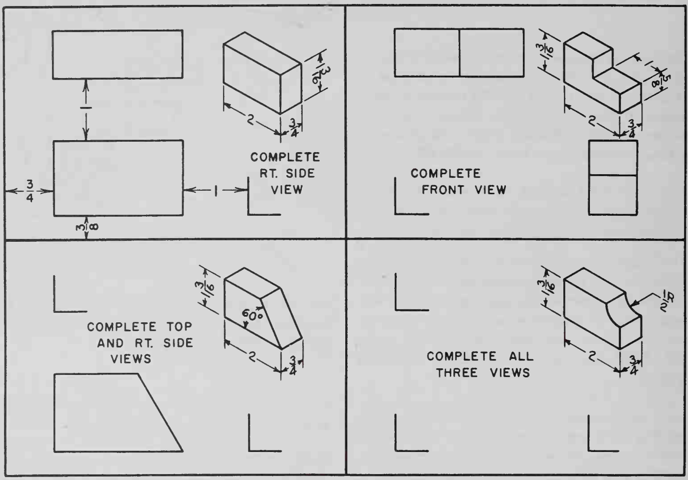


Fig. 3-8. Problems in multiview drawing.

DRAFTING ACTIVITY

1. Divide your plate into four sections.
2. First sketch, on another sheet of paper, the incomplete views; then you are to draw the views given and complete the views required in Fig. 3-8.
3. This is Plate No. 6. Number additional plates consecutively.
4. Sign your plate.

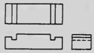
SELECTION OF VIEWS

The selection of views to represent an object is very important in drafting.

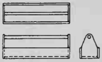
The drafter is the one who must decide on the number of views to be drawn as well as the choice of views. In a three-view drawing, usually the top, front and right-side views are drawn. In a two-view drawing the top and front views or the front and right-side views are drawn, depending on which ones best describe the object.

In selecting the views, give priority to the FRONT VIEW and consider the following suggestions:

1. Position the object so that the views will best describe its shape.

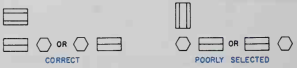


2. Position the object so that it is resting in its normal position.



3. Position the object so that the least number of hidden lines will be required.

4. Position the object so that the arrangement of the views fits the plate, resulting in good balance and economical use of space.



SPACING OF VIEWS

Before a working drawing is constructed, the spacing for the views must be figured. Let's see how this is done for a two-view drawing.

In Fig. 3-9 (a), a pictorial drawing of a bracket is shown. The working space of the plate is 10 1/2 in. wide by 7 3/8 in. high, Fig. 3-9 (b). To space the object horizontally, subtract the width of the object (6 in.) from the working-space (10 1/2 in.) and 4 1/2 in. remains (10 1/2 – 6 in. = 4 1/2 in.). Divide the 4 1/2 in. by 2 to get 2 1/4 in. for the spacing on each side of the object, Fig. 3-9 (b).

The vertical spacing is figured in a similar manner, but two views with spacing between these views are involved. Add the dimensions for the two views (2 + 1 1/2 in.) and the space between views (allowing at least 1 in., more space is necessary if several dimensions are to be placed between views). This totals 4 1/2 in. (2 in. + 1 in. + 1 1/2 in. = 4 1/2 in.). Subtract 4 1/2 in. from the working space (7 3/8 in.) and 2 7/8 in. remains. Divide this by 2 to get 1 7/16 in. for the spacing at the top and bottom of the plate, as shown in Fig. 3-9 (c).

Block in views lightly with construction lines, Fig. 3-9 (d). When you are certain of your layout, darken arcs and circles first, and then darken all straight lines, Fig. 3-9 (e). Spacing for a three-view drawing is figured in the same manner, except that spacing between the front and right-side views must be provided, Fig. 3-9 (f). Always figure your spacing on scrap paper before starting the layout of an object.

DRAFTING ACTIVITIES

1. Use plain notebook paper to sketch the three views of the pen holder base shown in Fig. 3-10.
2. Select views carefully and follow the sketching technique studies in Unit 2.
3. Submit sketch to instructor for approval.

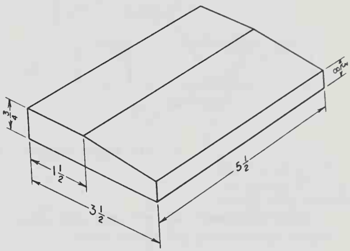


Fig. 3-10. Pen holder base.

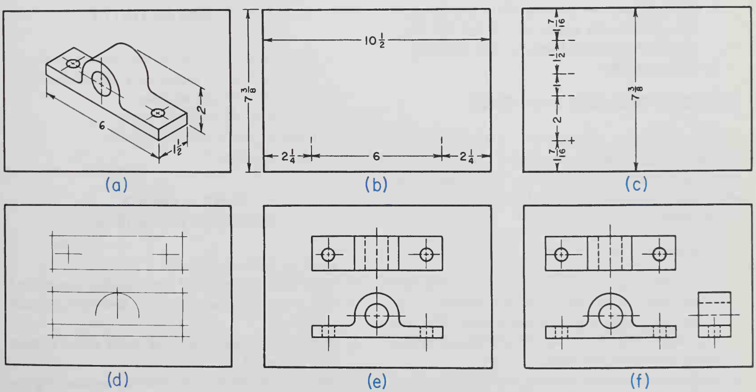


Fig. 3-9. Figuring the spacing for multiview drawings.

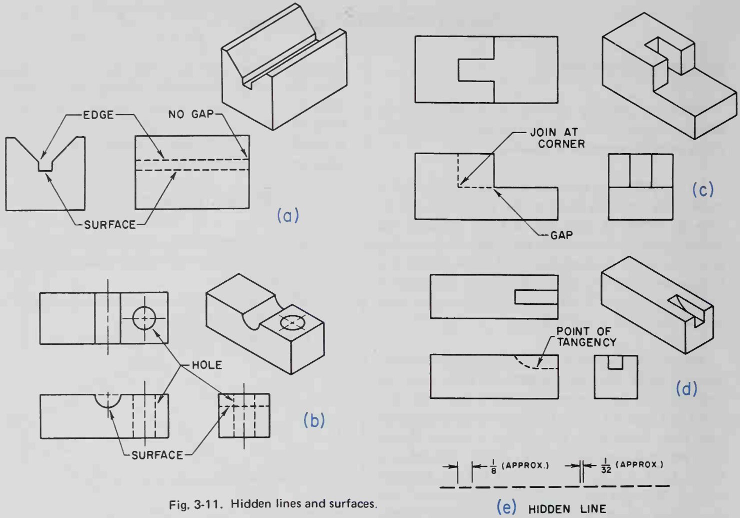


Fig. 3-11. Hidden lines and surfaces.

When your sketch has been approved, make a three-view drawing, using instruments.

1. Lay out border and title blocks but do not divide into sections.
2. Make a three-view drawing of the pen holder base. Follow the suggestions in Fig. 3-9 for layout of sheet and blocking in of the views.
3. Sign your plate.

HIDDEN LINES AND SURFACES

Edges, surfaces and corners not visible in a particular view are shown by hidden lines, Fig. 3-11. In this way, the worker is able to "see" hidden edges and better visualize the object. Note the construction of the hidden line in Fig. 3-11 (e).

When drawing hidden lines:

1. Start with a dash joining the object line, Fig. 3-11 (a). If the hidden line is a continuation of an object line, show a gap between object line and first dash, Fig. 3-11 (c). This indicates clearly where the object line stops.
2. Dashes join at hidden corners, Fig. 3-11 (c).
3. Hidden arcs begin with a dash at the point of tangency, Fig. 3-11 (d).

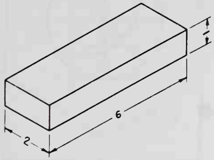
Hidden lines are sometimes omitted by experienced drafters when the drawing seems more clear without them, but you should include them unless otherwise directed by your instructor.

DRAFTING ACTIVITY

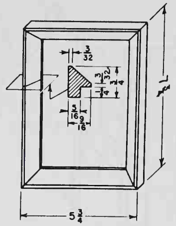
1. Select one or more of the objects in Fig. 3-12 and make a multiview drawing of each on a separate sheet of paper.
2. Draw only the necessary views.
3. Show all visible and hidden lines.
4. Sign your plate.

QUIZ – UNIT 3 WORKING DRAWINGS

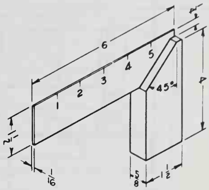
1. What is a working drawing?
2. What is the meaning of orthographic projection?
3. How many views are needed to describe a football field? Why?
4. What shop projects can you name which require only one view?
5. What things should you consider in selecting the views of an object?
6. Hidden lines are used for what purposes?



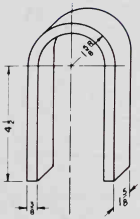
SHARPENING STONE



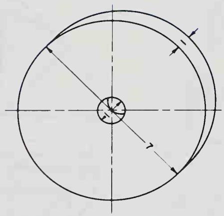
PICTURE FRAME



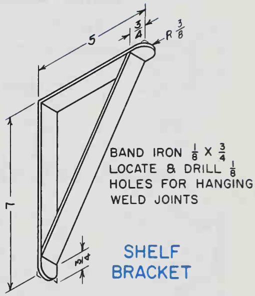
TRY-SQUARE



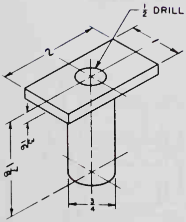
MAGNET



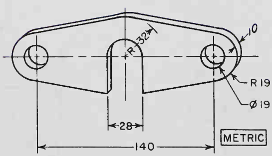
GRINDING WHEEL



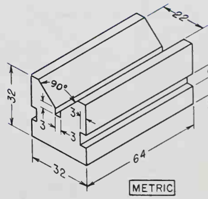
SHELF BRACKET



BENCH STOP

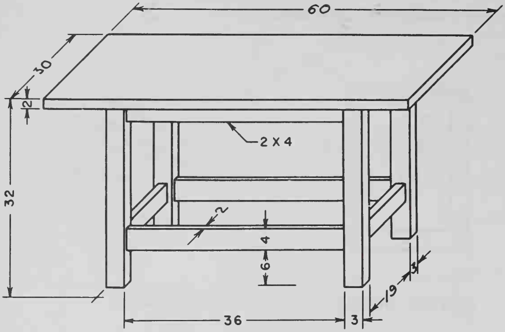


SLOTTED COUPLING

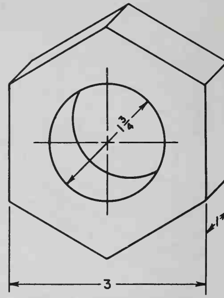


V-BLOCK

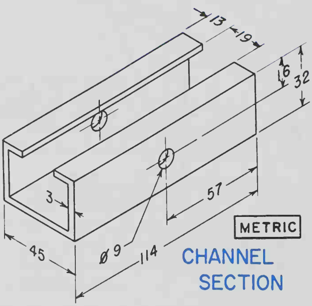
Fig. 3-12. Problems in multiview drawing.
(Additional problems on pages 38, 39, 40, 41.)



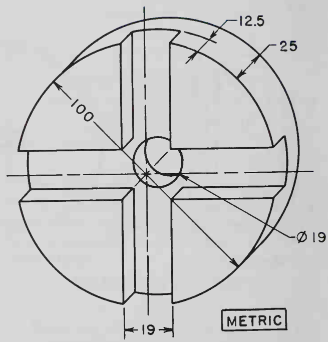
WORK BENCH



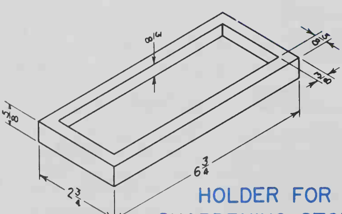
HEXAGONAL SPACER



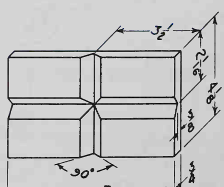
CHANNEL SECTION



CROSS PLATE

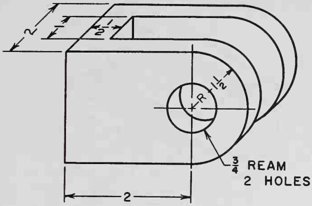


HOLDER FOR SHARPENING STONE

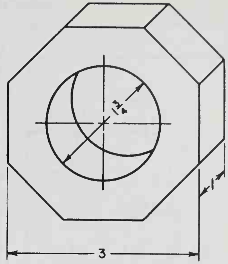


WOOD FACE FOR VISE

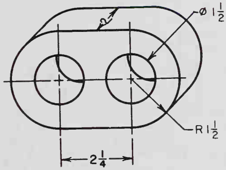
Fig. 3-12. (Continued) Problems in multiview drawing.



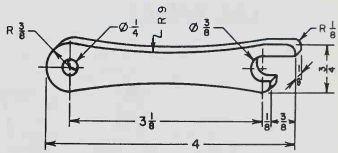
LINK



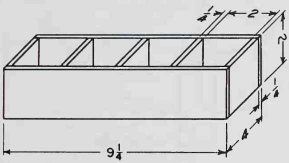
OCTAGONAL SPACER



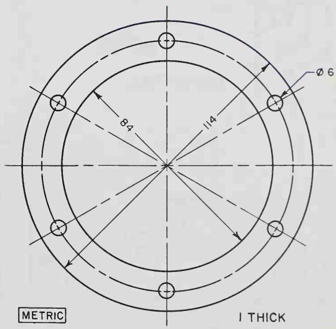
COUPLING



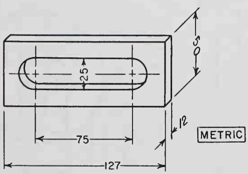
BOTTLE OPENER



NAIL BOX

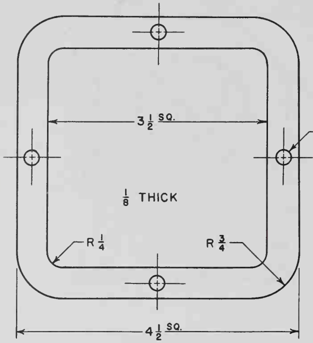


OIL GASKET

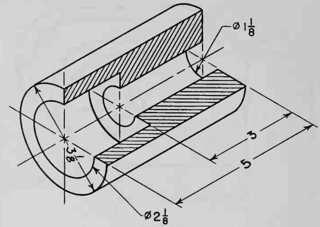


GUIDE PLATE

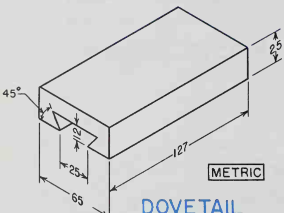
Fig. 3-12. (Continued) Problems in multiview drawing.



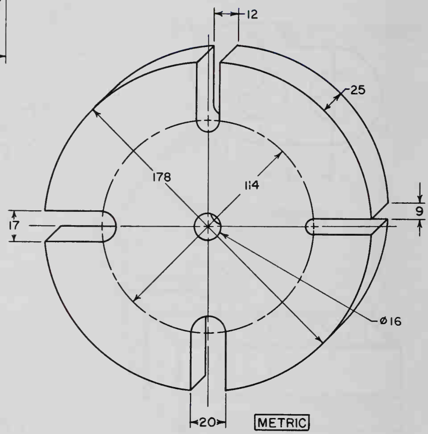
LINE GASKET



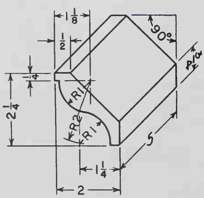
STEP BEARING



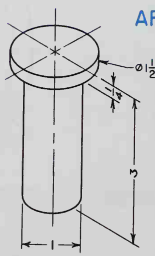
DOVETAIL



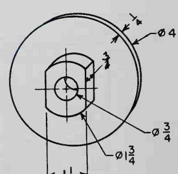
ARBOR PLATE



OGEE MOLDING

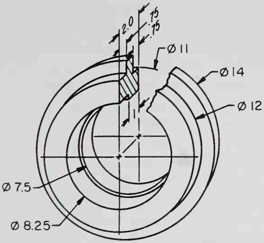


PIN

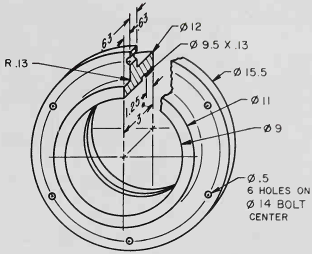


FACE PLATE BLANK

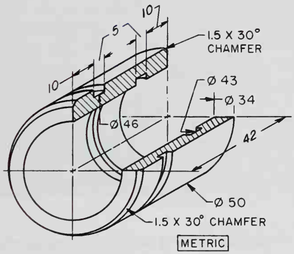
Fig. 3-12. (Continued) Problems in multiview drawing.



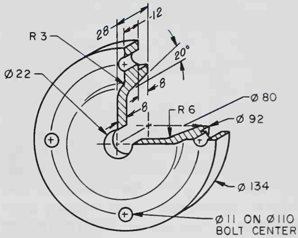
HUB



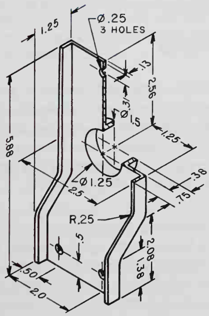
BEARING RETAINER



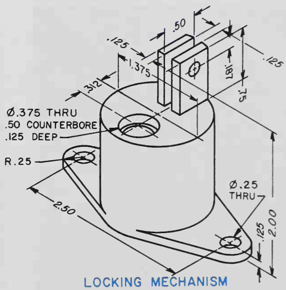
SPACER



CAP METRIC



SCRAPER BLADE MOUNT



LOCKING MECHANISM

Fig. 3-12. (Continued) Problems in multiview drawing.

DRAFTING CAREERS

1. **Is drafting in your future?**
2. **What do drafters do?**
3. **What careers are related to drafting?**

Does working with the T-square and triangles appeal to you? Have you the patience for accuracy and detail? Can you visualize three-dimensional objects readily? If you can answer "yes" to these questions, and if you have an interest in technical things, you may be interested in drafting or a related occupation as your life's work.

There are a number of careers to which an interest in drafting relates. These can be classified as jobs in drafting, engineering, architecture and industrial arts teaching.

DRAFTING

Jobs in drafting are usually grouped in five levels, depending on the type of work performed and skill required. The CHIEF DRAFTER plans and directs the work of the drafting department. He or she reviews the jobs coming into the department and assigns them to persons having the necessary skills and knowledge to perform the jobs. The DESIGNER designs, sketches and writes specifications for a workable product. To do this requires a thorough understanding of drafting, as well as a knowledge of manufacturing processes and materials. The designer may prepare the finished working drawings, or the sketch and specifications may be given to a DETAILER who will prepare the drawings.

After the working drawings are prepared, they are handed to a CHECKER who checks them for errors. This is important work, for any errors remaining in a drawing could cost a company a great deal of money in loss of time and material.

Sometimes industries desire a drawing which is more realistic in appearance for use in a handbook or other publication. This work is done by a TECHNICAL ILLUSTRATOR who improves the drawing by shading or adding color. Technical illustrators should have an understanding of the construction of pictorial views. They must know the mechanical aspects of the job and have the artistic ability to show the product in three dimensions.

All drafting positions require neatness, accuracy, normal vision and considerable technical knowledge. Many industries require previous training in drafting which can be acquired in high school drafting courses. For high level drafting positions, further education in a vocational-technical school or college is desirable and in some types of work, essential. In some industries, beginning drafters may learn the work through a three or a four-year apprenticeship. Training in related subjects such as English, math, physical science, electricity, metalwork, woodwork and other shop subjects is important. Usually the more training you have had upon entrance, the faster your advancement, and the higher your progress in drafting.

There is considerable opportunity for drafters in industry at the present time, and industrial trends indicate the demand will continue. See Fig. 3-13. Well-lighted rooms and clean surroundings make for desirable working conditions. The pay is good when compared with many other jobs in industry.

Long hours over the drawing board can be tiring and may cause eye strain. You will however, have the satisfaction of drawing, and perhaps designing, many industrial products. Drafting is an occupation of a technical nature which can be entered without four years of college training.

If you have drafting ability; get along satisfactorily in math, science and shopwork; are accurate and neat; you may want to investigate drafting as a career.

ENGINEERING

ENGINEERS work with ideas and problems related to the transformation of materials into useful products. As a beginner, an engineer may do some drafting, but later develop ideas for new products or work out mathematical and scientific solutions to problems which will be drawn by others.

Most professional engineering positions require from four to five years of college training. Success in a college program is dependent to a large extent upon your aptitude and ability in English, math and science courses, as well as technical subjects in engineering. Training in drafting and shopwork, although limited, is usually included in the college program.

With an expanding industrial economy, the employment outlook for engineers is likely to continue

Fig. 3-13. A drafting department in industry.
(Chevrolet Div., General Motors Corp.)

to be good. Salaries are among the highest paid in industry and the working conditions, like those for drafting, are pleasant.

If you have ability in drafting, math and science and like working with creative ideas, you may want to carefully consider a career in engineering.

INDUSTRIAL DESIGN

The industrial designer is involved with the development of useful products. The designer starts with an original idea for the product and carries it through its development to the final application. There are two major types of industrial designers — the product designer and the mechanical designer. The product designer designs "personal" machines or equipment which are used directly (electric shavers, portable power tools, automobile seats, steering wheels or sporting goods), Fig. 3-14. The mechanical designer works more directly with products that have a

Fig. 3-14. A turf riding golf course green mower developed by an industrial designer. (Toro Co.)

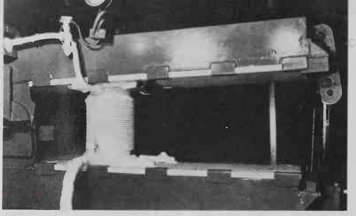


Fig. 3-15. A device for the cold cycle testing of a bellows. (Stainless Steel Products).

machine to machine relationship. These may be products such as a feed mechanism for a machine, an automatic transmission system for an automobile or a device for the testing of machine parts, Fig. 3-15.

Industrial designers must have inventiveness, a desire to improve product quality or operational features, and the ability to see relationships in mechanical things. They must possess knowledge and skill in drafting, technical illustration, science and math. An industrial designer's education usually requires four or five years of college.

The industrial designer's work is creative, and if you have an ability in sketching and drafting it may indicate you should consider this field as a career.

ARCHITECTURE

The architect designs buildings — houses, churches, schools, factories — and other structures with concern for construction, appearance and function.

Like engineers, the architect's training usually consists of four to five years of college with emphasis on English, math, science and technical courses. The architectural student ordinarily receives more training in drafting than the student engineer.

The opportunities for entering the field of architecture are favorable in view of our large residential and commercial building programs. The beginning architect usually starts as a junior drafter and with experience moves to chief drafter. Further work with an architectural firm leads to one of the specialized branches of construction supervision, specification writing, or designing of structures. About half of the architects in the United States achieve the goal of setting up their own businesses.

If you have ability in drafting, math and science, are creative and like artistic work, you may want to study further the field of architecture.

INDUSTRIAL ARTS TEACHING

Teachers of industrial arts instruct junior and senior high students in one or more areas, such as: drafting, electricity, graphic arts, metal, wood or crafts. Four to five years of college are required in the training of industrial arts teachers. Those interested in preparing for this field should have high aptitude and ability in drafting and shopwork, and a good background in English, math and science.

The demand for teachers of industrial arts is high and is likely to continue.

Industrial arts teachers enjoy pleasant working conditions, creative work and considerable freedom in planning their work.

If you do well in drafting and shop subjects, enjoy creating things, appreciate good quality craftwork and inventive design, you may want to consider teaching industrial arts. Ordinarily, industrial experience is not required, but it is highly recommended.

For additional information on these and other occupations related to drafting, talk to your industrial arts teacher or school counselor.

QUIZ — UNIT 3
DRAFTING CAREERS

1. Name the five types of drafting positions and describe the duties of each.
2. What are the requirements for entering the field of drafting?
3. Describe the work of the engineer and the qualifications for entering this field of work.
4. Name some products which you have around the house that were likely designed by an industrial designer.
5. What is the work of the architect and how much training is required?
6. What is the nature of the work of the industrial arts teacher and what are the requirements for entering this field of work?

Unit 4
LETTERING AND DIMENSIONING

After studying this unit, you will know:
1. What kinds of lettering to use on drawings.
2. How letters and numerals are constructed.
3. How drawings are dimensioned.
4. What is simplified drafting.

All industrial drawings, with the possible exception of a hurried shop sketch, contain information which is lettered. The lettering and dimensioning on your plates will affect the appearance of your work just as much as your technique with instruments and sketching. In this unit you will want to begin to develop this skill so that you can start lettering and dimensioning your plates.

STYLE OF LETTERING

Two types of Gothic lettering are used – vertical and inclined, Fig. 4-1. The vertical letters are perpendicular to the line of lettering, as the name suggests,

VERTICAL GOTHIC LETTERS

INCLINED GOTHIC LETTERS

Fig. 4-1. Gothic lettering.

and the inclined letters are formed at a forward angle of 68 deg. The Gothic style refers to letters that are formed with single strokes of the pencil or pen rather than letters that vary in thickness, such as the Roman, Fig. 4-2. Gothic lettering can be done much more readily and is easier to read than other styles. For these reasons, it has become universally accepted as the style of lettering for all industrial drawings.

In Fig. 4-3 are shown the vertical Gothic capitals (upper case), the small letters (lower case), and numerals as well as the strokes used in forming these. The inclined Gothic letters and numerals are shown in Fig. 4-4.

AB

Fig. 4-2. Roman lettering.
(Higgins Ink Co., Inc.)

Both the vertical and inclined styles are used in industrial drawings; therefore, you should learn to use each style. Your instructor will help you decide which style to use with your beginning drawings.

Capital letters (caps) are used for title block information and for notes, Fig. 4-5 (a). Occasionally, capitals and lower case (lc) letters are used for notes, particularly on map drawings, Fig. 4-5 (b). You may use your 2H pencil for lettering, or you may want to get one with a softer lead, such as an F or HB.

SIZE OF LETTERS

The size of letters varies with the size of the drawing. In your work you will follow the suggested letter sizes for the title block. You should use 1/8 in. capitals for notes on drawings unless otherwise directed by your instructor. When lower case letters are used with capitals, the body of the lower case letter is two-thirds the height of the capital. A few lower case letters are as tall as caps, extending either above or below lower case guide lines, Fig. 4-6.

Numerals are equal in height (H) to capital letters, and fractions are twice the height of whole numbers, Fig. 4-7.

The space between letters, words and sentences is judged by the eye. You must exercise care in seeing that the spacing is compact but not crowded, Fig. 4-8.

Fig. 4-3. Strokes and proportions, vertical Gothic lettering.
(Higgins Ink Co., Inc.)

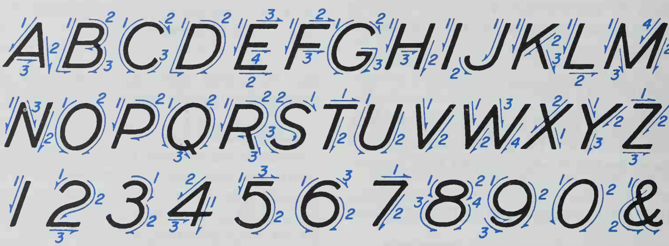


Fig. 4-4. Strokes and proportions, inclined Gothic lettering.
(Higgins Ink Co., Inc.)

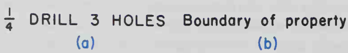


Fig. 4-5. Notes on drawings.

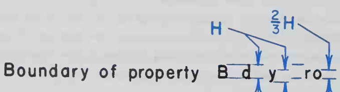


Fig. 4-6. Size of letters.

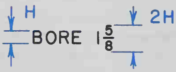


Fig. 4-7. Numerals and fractions.

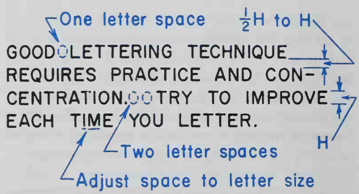


Fig. 4-8. Spacing letters, words and lines.

Fig. 4-9. Horizontal guide lines.

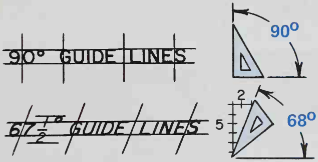


Fig. 4-10. Vertical and inclined guide lines.

GUIDE LINES

Horizontal guide lines assist in keeping your lettering in line and uniform in height. Use them for all lettering – one numeral or several lines of notes, Fig. 4-9.

Vertical or inclined guide lines should be used as a guide to the correct slope of letters, Fig. 4-10.

Guide lines should be drawn lightly so that erasures are not required, and they should be invisible at an arm's length. Use a sharp 4H pencil or your 2H VERY LIGHTLY.

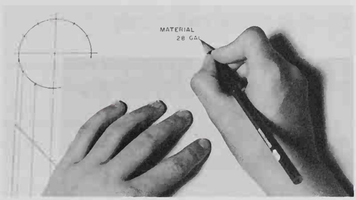


Fig. 4-11. Protect your work when lettering and dimensioning.

POSITION FOR LETTERING

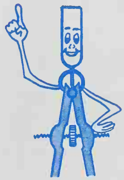
Lettering should be done with the arm and hand supported on the drawing table or board. The pencil should be held with a relaxed grip as in writing. Place a sheet of paper or cloth under your hand and arm, to protect your drawing when lettering. Fig. 4-11.

LETTERING SAMPLES

Samples of lettering carelessly done and samples properly lettered appear in Fig. 4-12.

Your skill in lettering can best be developed by:

1. Doing a short lettering exercise to acquaint you with the strokes necessary to form letters and numerals correctly.
2. Lettering your plates.
3. Practicing during your free time outside class.



DRAFTY SAYS:

"Strive for neatness and accuracy in all drafting problems."

AIDS TO GOOD LETTERING

Instruments are available for use in laying out guide lines for lettering, Fig. 4-13. Perhaps your instructor has one of these.

POOR		GOOD
YOUR LETTERING	Spacing crowded	YOUR LETTERING
SPEAKS FOR	Spacing loose	SPEAKS FOR
YoUR DRAWING.	Height not uniform	YOUR DRAWING.
LET IT SPEAK	Incorrect slope	LET IT SPEAK
WELL. TAKE	Poorly formed letters	WELL. TAKE
PRidE IN All	Do not mix caps and lc	PRIDE IN ALL
THAT YOU DO.	Letters too heavy	THAT YOU DO.

Fig. 4-12. Your lettering affects the appearance of your work.

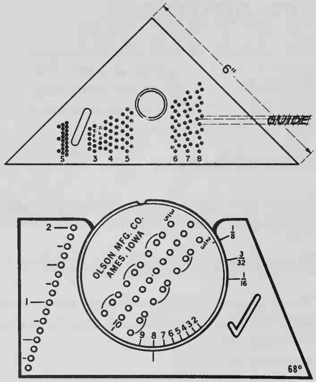


Fig. 4-13. Lettering instruments.

Fig. 4-14. Lettering devices. (Keuffel & Esser Co. and Wood-Ragan Instrument Co., Inc.)

LETTERING DEVICES

Many professional drafters use lettering devices for lettering their drawings, particularly when the lettering is on sheets from which prints are to be made. Two such devices are shown in Fig. 4-14. However, far more drawings are lettered by freehand than are lettered with the use of instruments.

DRAFTING ACTIVITY

1. Divide your plate into four sections.
2. Letter 1/8 in. alphabets and numerals in section A. Allow 1/8 in. between lines.
3. Use horizontal guide lines, and vertical or inclined guide lines.
4. Refer to your lettering charts, Figs. 4-3 and 4-4, when lettering.
5. Your instructor will tell you when the other sections are to be lettered.

DIMENSIONS AND SHOP NOTES

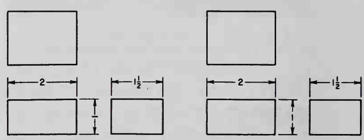
Drawings provide the drafter with two essentials: shape description through the views, and size description through dimensioning. Notes furnish other information such as kind of material, finish and quantity.

You are now familiar with the theory of shape description. Information regarding size description will be discussed here under dimensioning practices.

DIMENSIONING PRACTICES

Dimensions indicate size of objects and location of parts. Let's look at some dimensioning practices.

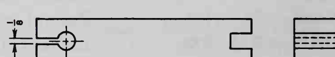
1. Dimensions are placed to be read either from the bottom of the sheet (unidirectional) or from the bottom and right side (aligned).



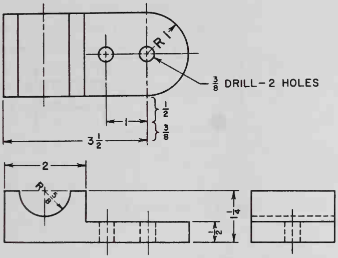
ALIGNED DIMENSIONS UNIDIRECTIONAL DIMENSIONS

USE ONLY ONE SYSTEM ON A DRAWING

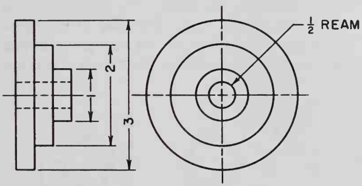
2. Dimensions on a simple drawing are placed between views. Exceptions may be made for purposes of clarity.



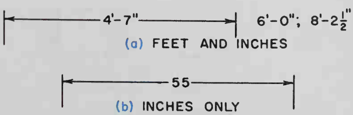
3. Dimensions are placed adjacent to view most descriptive of shape dimensioned.



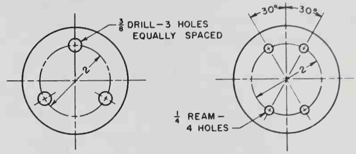
4. Dimension lines are spaced at least 1/2 in. from view; additional dimensions 3/8 in. apart (see illustration item 3). Never crowd dimensions.
5. Smaller dimensions are placed nearest the object. Over-all dimensions are always given for height, width and depth (see illustration item 3).
6. Circles are dimensioned by giving the diameter in the rectangular view. Shop notes are directed to the circular view.



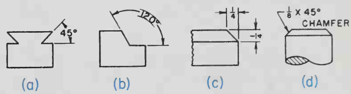
7. Dimensions are staggered for ease of reading (see illustration item 6).
8. Symbols for feet (') and inches (") are used. When all dimensions are in inches, the inch marks should be omitted.



9. The radius (R) is used in dimensioning arcs. The "R," located above the dimension line, always follows the dimension (see illustration item 3).
10. Holes are located around a common center by dimensions and shop notes.



11. Angles are indicated by degrees, on an arc swung from the vertex, (a) and (b). For angles less than 90 deg., dimensions are placed horizontally, (a); for larger angles on the contour, (b). Some angles such as a chamfer require two dimensions, (c) and (d).



DIMENSIONING SMALL SPACES

Crowding dimensions into a small space produces poor drawings. Instead, try the methods shown in Fig. 4-15.

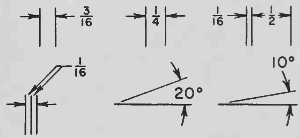


Fig. 4-15. Dimensioning small spaces.

ARROWHEADS

Drafters should be as careful in forming their arrowheads as the Indians were in forming theirs. It's true that drafting arrowheads are not made to spear game, but they are designed to POINT TO EXACT SPOTS on the drawing. So it is important that they be "sharp" and well balanced, as shown in Fig. 4-16 (a). Draw each half of the arrowhead with your lettering pencil in one stroke toward and away from the point. Fill in the arrowhead for a neat appear-

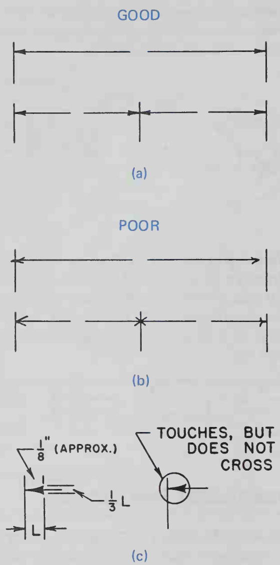


Fig. 4-16. Arrowheads.

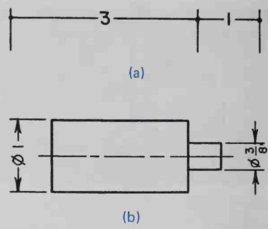


Fig. 4-17. Functional drafting.

ance, Fig. 4-16 (c). The length is usually 1/8 in. and should be uniform on each drawing. Make the width about 1/3 of the length.

Take pride in the formation of arrowheads, letters, and numerals, and your efforts will be rewarded.

FUNCTIONAL DRAFTING

In some industries "functional drafting" is being used. This is a term applied to drafting procedures in which "shortcuts" are taken and yet accuracy is still maintained in the work. Examples of functional drafting practices would be: the substitution of dots for arrowheads, Fig. 4-17 (a); the drawing of only one

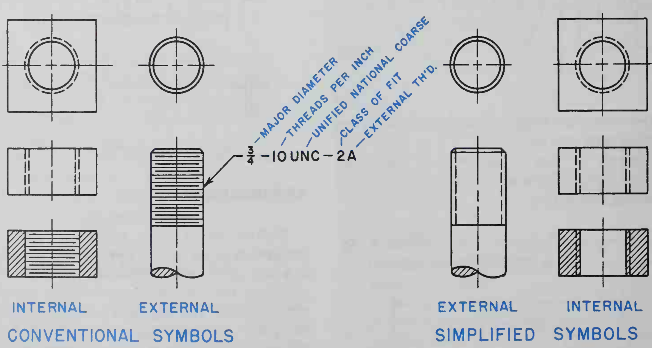


Fig. 4-18. Conventional and simplified representation of machine threads.

view of an object and indicating the thickness or diameter, Fig. 4-17 (b); the use of freehand sketches in place of instrument drawings; and the use of abbreviations and symbols on drawings. Machine screw threads of 1 in. in diameter or less are usually drawn as conventional symbols or in simplified form rather than in their true shape, Fig. 4-18. Functional drafting practices may differ in each industry using the system.

Because the standard system is used in most industries as well as in schools, you should first study this system. Once you understand this system you will then be in a position to judge when functional drafting can be used most effectively.

DRAFTING ACTIVITY

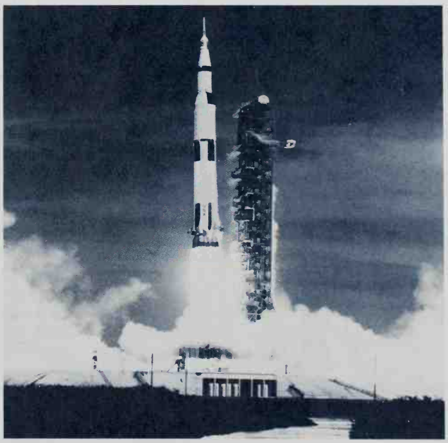
1. Study the alphabet of lines, page 121 as it pertains to dimension lines, extension lines and leaders.
2. Dimension and letter the drawings which you completed earlier.

QUIZ – UNIT 4

1. Why is the Gothic style of lettering used on industrial drawings?
2. What are the two styles of Gothic lettering used in drafting?
3. When should you use capital letters? Lower case letters?
4. How high should capital letters be on your plates? Lower case letters? Numerals and fractions?
5. How much space is placed between words? Between sentences?
6. When should horizontal guide lines be used? Vertical or inclined guide lines? What weight should they be drawn?
7. How may you protect your drawing when you are lettering or dimensioning?
8. What information is generally supplied by the shop notes?
9. How large should arrowheads be drawn on your drawing?
10. Tell what is meant by simplified drafting and give some examples.

NEW WORDS FOR YOU TO USE

1. Dimension (di-men'shun)
2. Gothic (Goth'ik)
3. Simplified (sim'pli-fied)
4. Staggered (stag'er-ed)



Industry photo. Many drafting skills are needed for today's careers. (NASA)

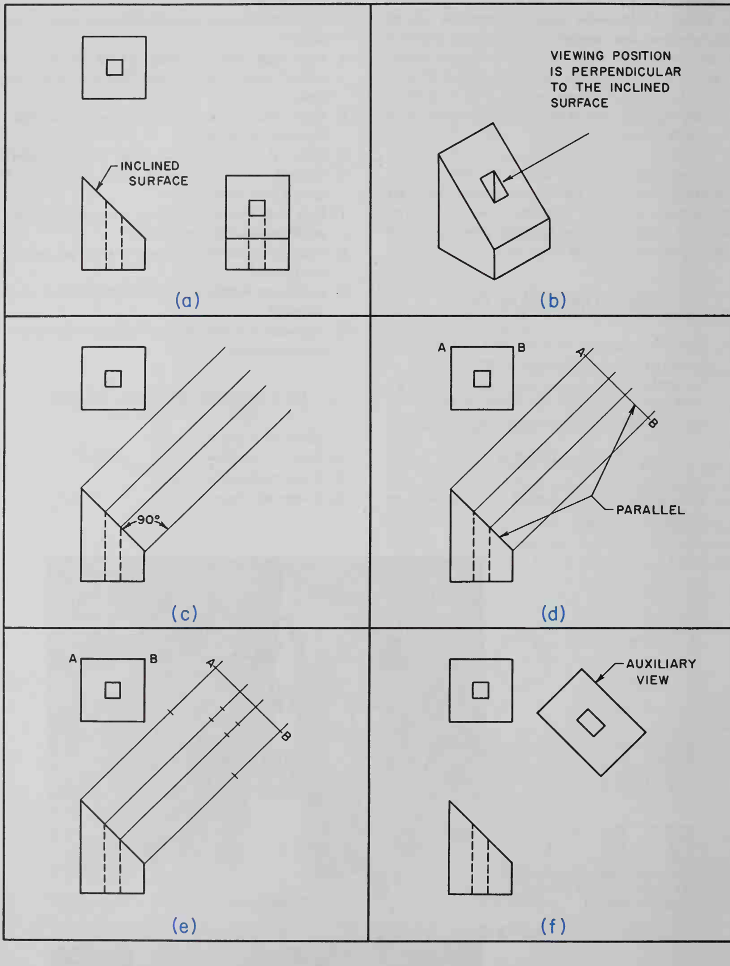


Fig. 5-1. Drawing an auxiliary view.

Unit 5
AUXILIARY AND SECTIONAL VIEWS

After studying this unit, you will know:
1. What are auxiliary views.
2. What are sectional views.
3. How auxiliary and sectional views are used in drafting.

In addition to the regular views in a working drawing, it is sometimes necessary to draw some "special" views of an object, to show more clearly certain features. Two of these special views are AUXILIARY VIEWS and SECTIONAL VIEWS.

Auxiliary views are used in obtaining the true size and shape of inclined surfaces such as the one shown in Fig. 5-1.

Sectional views show the object as if a part of the object were removed and you could view its internal shape, Fig. 5-2.

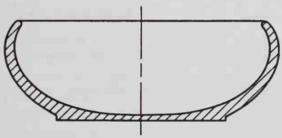


Fig. 5-2. Sectional view of a bowl.

Both of these views are quite helpful to the workman. You will want to know how they are drawn.

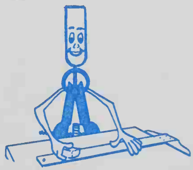
AUXILIARY VIEWS

Suppose you had to lay out on a piece of sheet metal the true size and shape of the inclined surface in Fig. 5-1 (a). A true representation of this surface does not appear in any of the three views. However, an auxiliary view can be projected which would be a true representation. Let's see how it is developed.

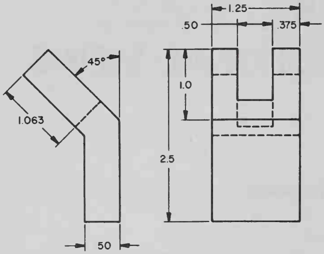
1. The inclined surface is viewed from a positon perpendicular to the surface, Fig. 5-1 (b).
2. Usually, not more than two regular views are needed to project the auxiliary view; the view in which the inclined surface appears as a line (front view, Fig. 5-1 (a)) and one other view, such as the top view.
3. Construction lines (very light) are projected perpendicular from the inclined surface, Fig. 5-1 (c).
4. The reference (back-edge) line AB is drawn parallel to the inclined surface, Fig. 5-1 (d).
5. The dividers are used in transferring widths from the top view, Fig. 5-1 (e). Care is taken not to punch holes in the drawing with the divider points.
6. Lines are drawn to complete the auxiliary view in Fig. 5-1 (f). Actually, more than the inclined surface is visible from the auxiliary plane, but usually only the inclined surface is shown.

Auxiliary views can be projected from any view in which the inclined surface appears as a line. In the preceding problem the projection was made from the front view and, therefore, is known as a front auxiliary. A projection from the top view would be called a top auxiliary and from the right side, a right side auxiliary.

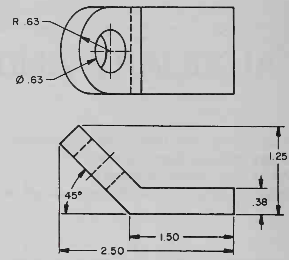
You will find your knowledge of auxiliary views very helpful when you are working with the unit on sheet metal drafting.



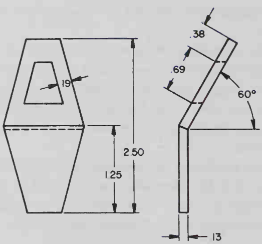
DRAFTY SAYS: "Don't forget to clean your T-square and triangle occasionally with a soft eraser and cloth."



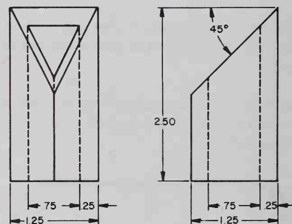
ANGLE BRACKET



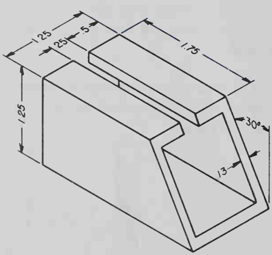
OFFSET PLATE



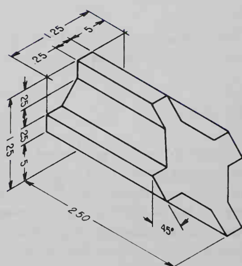
COVER PLATE



ALUMINUM EXTRUSION



CHANNEL ANGLE CUT



SPLINE ANGLE CUT

Fig. 5-3. Auxiliary problems.

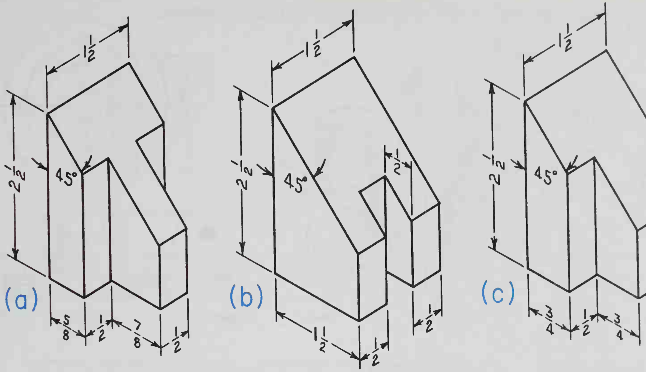


Fig. 5-3. (Continued) Auxiliary problems.

DRAFTING ACTIVITY

1. With your instructor's approval, select one or more of the problems in Fig. 5-3.
2. Draw two views and an auxiliary view.

SECTIONAL VIEWS

Several of the major automobile manufacturers have exhibited, throughout the country, engine and chassis assemblies of their cars. Perhaps you have seen one of these exhibits and noticed the cutaway sections of carburetors, gear-mechanisms and cylinder blocks, Fig. 5-4. The sections have been removed to show the operation of the various parts.

The purpose of the SECTIONAL VIEWS in drawing is to show more clearly the shape and operation of complex objects. Let's see how the FULL SECTION and the HALF SECTION are constructed.

First, imagine a cutting plane has cut the object in half, Fig. 5-5 (a). Next, imagine that the front half has been removed, Fig. 5-5 (b). What you would be viewing is a FULL SECTION since our cutting plane has passed all the way through the object. The section lines have been drawn to further clarify the interior shape of the object at the cutting plane. Notice the cutting plane line in the top view of Fig. 5-5 (c). The arrows indicate the direction of sight.

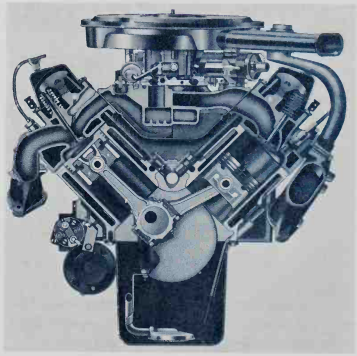


Fig. 5-4. Sectional view of a car engine. (Cadillac Motor Car Div.)

A HALF SECTION would be a view in which the cutting plane passes only half way through an object and one quarter of the object is removed, Fig. 5-6. Other types of sectional views are shown in Fig. 5-7.

SECTION LINES

Section lines are usually drawn at an angle of 45 deg. with a sharp 2H pencil, Fig. 5-5 (c). Draw the

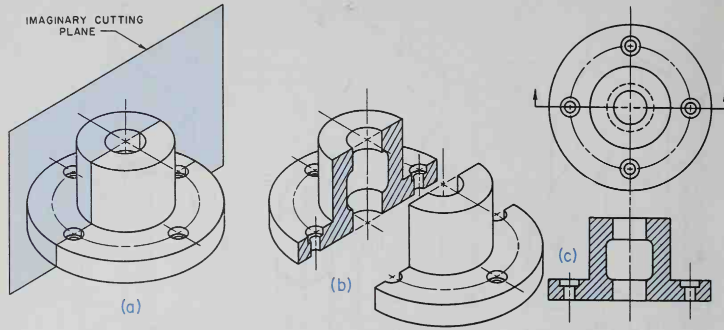


Fig. 5-5. A view of a full section.

lines dark and thin to contrast with the heavier object lines. Space the lines by eye about 1/16 in. apart (on small drawings about 1/32 in.; large drawings, 1/8 in.). The spacing of section lines should be uniform.

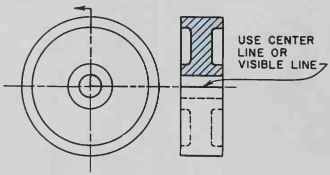


Fig. 5-6. Half section.

The shape and position of the object sometimes require that section lines be drawn at a special angle, for example 30 deg., to prevent the section lines from being drawn parallel or perpendicular (or nearly so) to a prominent visible line bounding the sectional area, Fig. 5-8. Section lines change direction for adjacent parts, Fig. 5-9. Center lines are drawn in sectional views, but hidden lines are omitted unless they are needed for clarity.

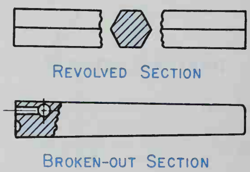


Fig. 5-7. Other types of sections.

The section lines shown in these sectional views are those used to indicate cast iron. However, when

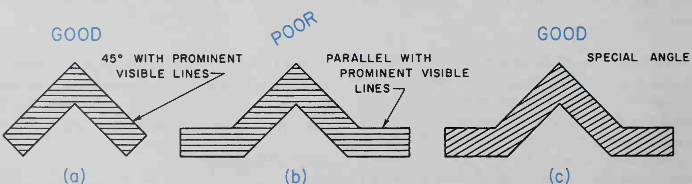


Fig. 5-8. Angle of section lines.

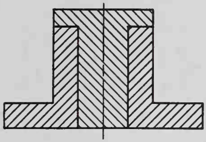
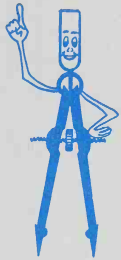


Fig. 5-9. Sectioning of adjacent parts.



the section lines are not being used as a symbol to indicate type of material, this type of sectioning is commonly used for other materials. See Fig. 5-10 for specific representation of other materials in section.

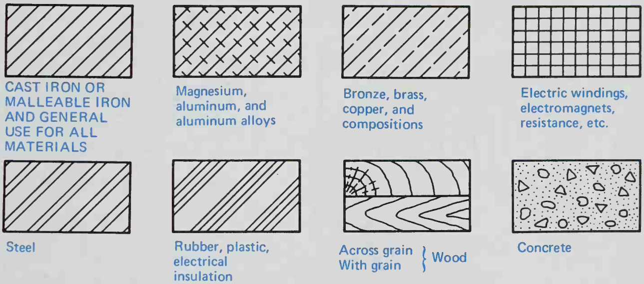


Fig. 5-10. Symbols for materials in section. (ANSI Y 14.2-1973-Line Conventions and Lettering.)

DRAFTING ACTIVITY

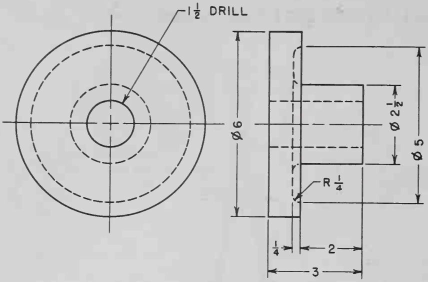
1. With your instructor's approval, select one or more of the problems in Figs. 5-11 and 5-12, pages 58 and 59.
2. Draw two views, one representing a full section.
3. Dimension the drawing.

QUIZ – UNIT 5

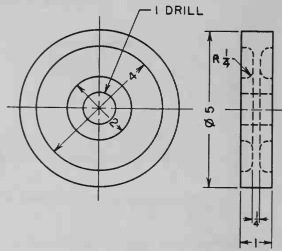
1. The auxiliary view is projected from what view? Why?
2. How many views are needed in projecting an auxiliary view?
3. When would you use an auxiliary view?
4. What is a right side auxiliary view?
5. Sectioning of an object is used for what two purposes?
6. How does a full section differ from a half section?
7. Section lines are usually drawn at an angle of 45 deg. When would it be necessary to draw them at an angle other than 45 deg.?
8. When would you use the cast iron section lining to represent materials other than cast iron?

NEW WORDS FOR YOU TO USE

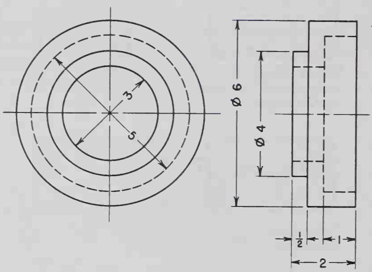
1. Auxiliary (og-zil'ya-ri)
2. Section (sek'shun)



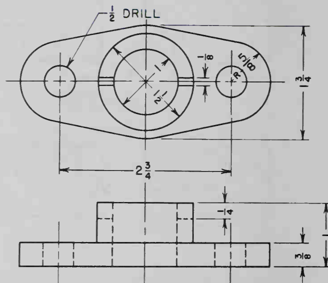
PLATE



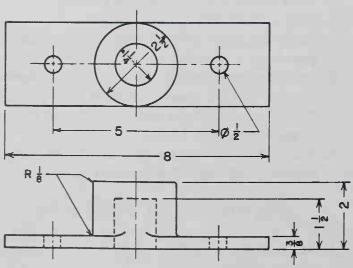
BRONZE ROLLER



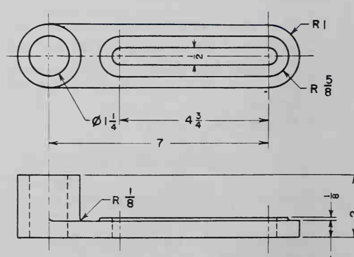
MACHINED CAP



SLOTTED BRACKET



BEARING CAP



TOOL REST BASE

Fig. 5-11. Sectioning problems.

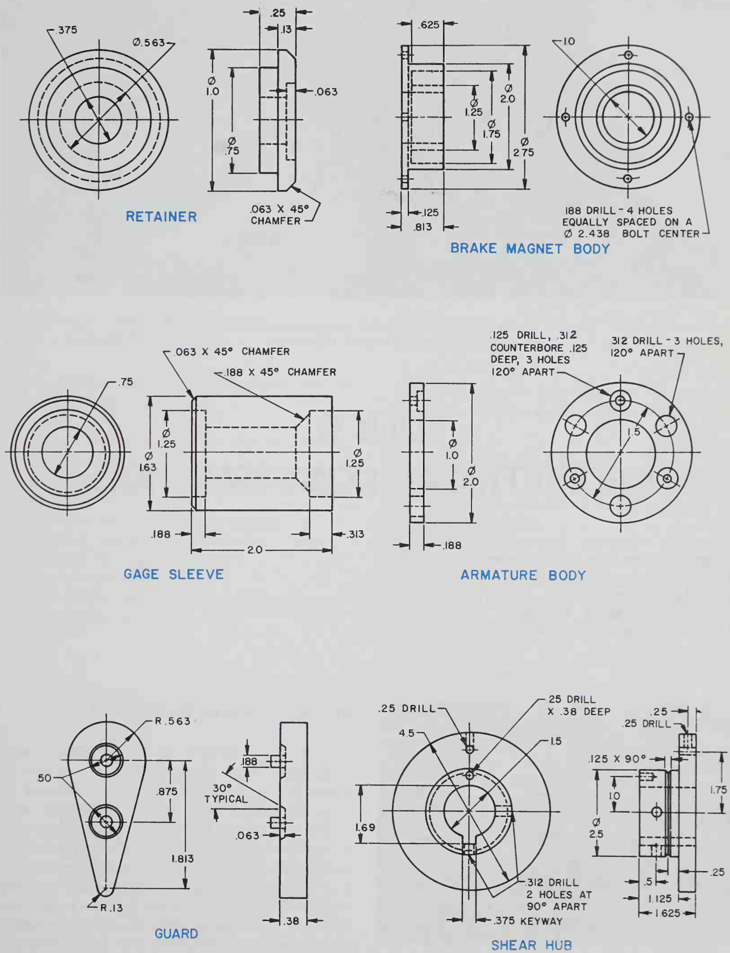


Fig. 5-12. Additional sectioning problems.

Fig. 6-1. Geometry applied to bridge construction.
(Missouri State Highway Department)

Unit 6
GEOMETRICAL CONSTRUCTION

After studying this unit, you will know:
1. **How geometry relates to drafting.**
2. **What is a polygon.**
3. **How pentagons, hexagons and octagons are constructed.**
4. **How a 5-point star is constructed.**

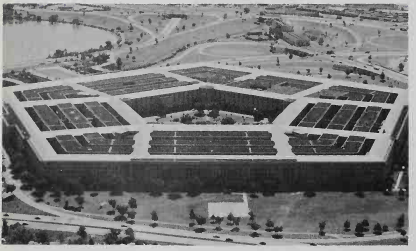


Fig. 6-2. The pentagon in Washington, D. C.
(Official U. S. Air Force Photo)

APPLICATIONS OF GEOMETRY

In our daily activities we come in contact with many applications of geometry. One example is shown in Fig. 6-1. You have already learned to construct a good many geometrical figures: arcs, circles, squares and triangles. In addition you have learned how to divide a space, or a line, into an equal number of parts. You will also want to learn how to draw polygons. A polygon is a plane geometric figure enclosed with straight lines on three or more sides. Three and four-sided polygons are the most common types (triangles, squares, rectangles). The Pentagon in Washington, D.C. is a good example of a five-sided polygon used in architecture. See Fig. 6-2.

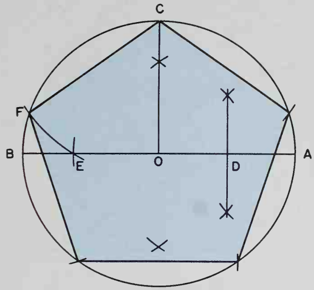


Fig. 6-3. Construction of a pentagon.

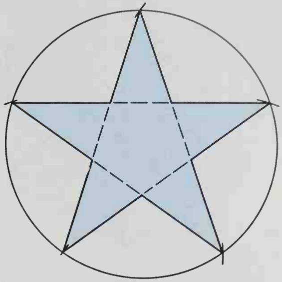


Fig. 6-4. Five-point star.

CONSTRUCTING A PENTAGON AND A 5–POINT STAR

The pentagon (5 sides) and the 5-point star are constructed as follows:

1. Draw a circle equal to the size of pentagon desired, Fig. 6-3.
2. Construct diameter, AB and radius OC perpendicular to AB.
3. Bisect line AO to find center point D.
4. Draw CE using point D as the center.
5. Draw arc EF from center point C.
6. Draw the line CF.
7. Lay off the four remaining sides, equal to CF, around the circle.
8. Connect the points around the circumference to form a pentagon.

To form a 5-point star locate the five points as above and connect the points as shown in Fig. 6-4.

DRAFTING ACTIVITY

1. Lay out plate using Plan A border and divide into four sections.
2. In section A, construct a pentagon inside a 3 in. circle. Make light construction lines and darken pentagon when completed.
3. In section B, construct a 5-point star inside a 3 in. circle.

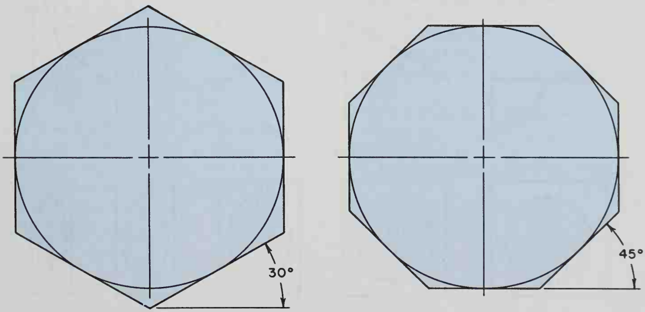


Fig. 6-5. Constructing the hexagon and octagon with the T-square and triangles.

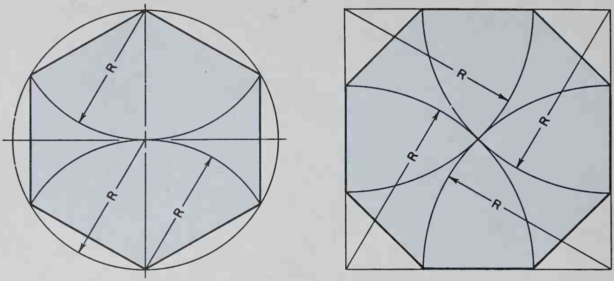


Fig. 6-6. Constructing the hexagon and octagon with the compass.

CONSTRUCTING HEXAGONS AND OCTAGONS

The hexagon (6 sides) and the octagon (8 sides) can be constructed by first drawing a circle equal to the polygon desired. The sides are located as shown in Fig. 6-5.

If the hexagon and octagon are to be drawn on material where the T-square and triangles cannot be used, follow the procedures in Fig. 6-6.

DRAFTING ACTIVITY

1. In section C, construct a hexagon within a 3 in. circle, using only the compass and a straightedge.
2. In section D, construct an octagon inside a 3 in. square. You may use the T-square and the triangle to construct the square, but use only the compass and a straightedge to construct the octagon.

CONSTRUCTING AN ELLIPSE

An ellipse is formed when a circle is viewed at an angle, Fig. 6-7. Ellipses may be drawn with the aid of an ellipse template or an approximate ellipse may be constructed mechanically with the four-center approximation method, Fig. 6-8. The procedure for

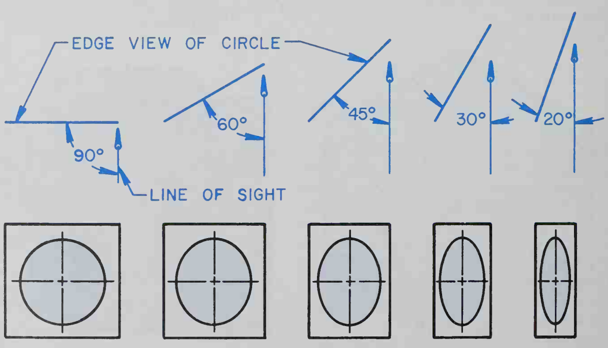


Fig. 6-7. When a circle is rotated on its axis away from an angle perpendicular to the line of sight, an ellipse is formed.

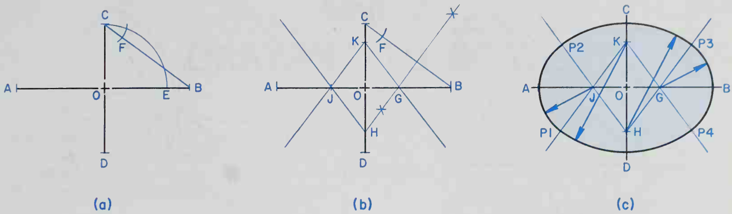


Fig. 6-8. Constructing the four-center approximate ellipse.

constructing a four-center approximate ellipse is as follows:

1. The major axis AB and minor axis CD are given, Fig. 6-8 (a).
2. Draw the line CB, and using the center 0 and the radius OC, draw an arc intersecting OB at E.
3. With the radius EB and using C as the center, strike an arc intersecting CB at F.
4. Construct a perpendicular bisector of line FB and extend to intersect with the major and minor axes at G and H, Fig. 6-8 (b).
5. Points G and H are the centers for two of the four arcs of the ellipse; with a compass and using 0 as the center, locate J and K similar to G and H.
6. Draw a line from H extending through J, and lines from K through J and G.
7. Using centers J and G, draw arcs JA and GB from P1 to P2 and P3 to P4, Fig. 6-8 (c).
8. With H and K as centers, strike arcs HC and KD from P2 to P3 and P4 to P1 to complete the four-center approximate ellipse.

DRAFTING ACTIVITY

1. Use a plan B sheet layout and divide the work space in half. Draw a four-center approximate ellipse in the top space with a major diameter of 3 inches and a minor diameter of 1 1/4 inches.
2. In the bottom space, draw a four-center approximate ellipse with a major diameter of 4 inches and a minor diameter of 2 inches.

DRAFTING ACTIVITY

1. Make a one view drawing of the designs shown in Fig. 6-9 as assigned by your instructor.
2. Make your own geometric design using variations and combinations of the figures in Fig. 6-9.
3. Using geometric figures, design a cover for your notebook or for a surface design on a piece of wood or leather.

QUIZ – UNIT 6

1. Name as many geometrical figures as you can and give an example of the use of each in life.
2. What are polygons?
3. Of what importance is accuracy in laying out geometrical forms?
4. What use can you make of geometrical construction?
5. What is an ellipse? Name two ways of drawing an ellipse.

NEW WORDS FOR YOU TO USE

1. Geometry (je-om'e-tri)
2. Polygon (pol'i-gon)

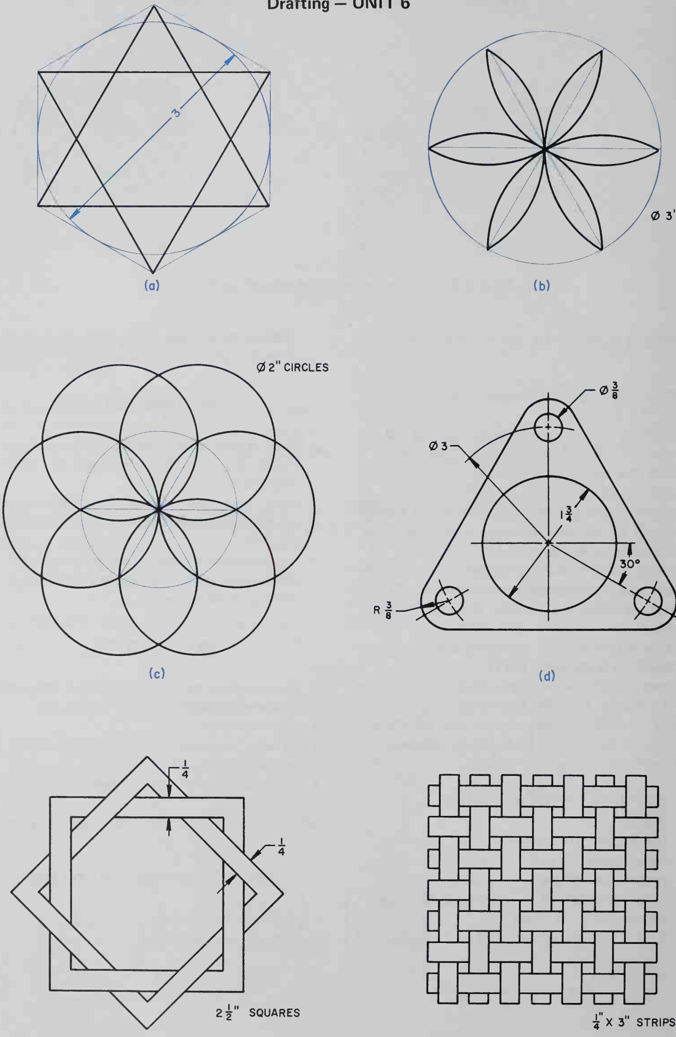


Fig. 6-9. Geometric designs.

Unit 7
DRAWING TO SCALE

After studying this unit, you will know:
1. What drawing to scale means.
2. What different types of scale are used in drafting.
3. How scale measurements are made.

You have already learned to use the full-size scale in drawing an object full size. In drafting it is often necessary to make the drawing of an object smaller than its actual size. You have probably seen blueprints for a house. These had to be reduced considerably in size in order to get it on a reasonable size sheet of paper. Sometimes it is necessary for the drafter to enlarge the drawing of a small screw or machine part in order to show the details clearly.

The secret of this reduction or enlargement of drawings is in the drafters' scale, where it is all worked out for them – if they know how to use it!

TYPES OF SCALES

There are three English (customary) scales in common use: those designed for the architect, the civil engineer and the mechanical engineer. Also, the metric scale is coming into use in the U.S. The architect's scale has a full-size scale of 12 in. marked off into 16ths. You have been using this full-size scale. The architect's scale also has a number of other scales divided into inches or fractions of an inch which represent feet. These scales are used in construction plans and for all objects dimensioned in feet and inches.

The civil engineer's scale, Fig. 7-1, is similar to the architect's scale, except the graduations are divided into decimal parts of an inch; usually 10, 20, 30, 40, 50 and 60 parts to an inch. This scale is useful in the drawing of aircraft and automotive machine parts where the decimal system has largely replaced the fractional system of dimensioning. It is also used in map drafting.

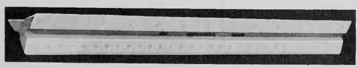


Fig. 7-1. Triangular civil engineer's scale.

The mechanical engineer's scale is laid out so that the major end unit represents one inch rather than one foot.

The metric scale is a decimal scale either full size or a fractional size, such as 1/50th size.

If you learn to read one type of scale, you can also read other scales with a little help on the numbering system. Let's have a look at the architect's scale.

MEASURING WITH THE ARCHITECT'S SCALE

Four commonly used scales are:

Full-size or, 12″ = 1′ - 0″

Half-size or, 6″ = 1′ - 0″

Quarter-size or, 3″ = 1′ - 0″

Eighth-size or, 1 1/2″ = 1′ - 0″

The first of these (full-size) you have been using. If you want to draw an object half its actual size, you simply let 1/2 in. on the full-size scale represent 1 in. On the HALF-SIZE SCALE a distance of 3 1/2 in. would be measured as shown in Fig. 7-2.

Reading the half-size scale is easy when you let each half-inch represent one inch. The quarter-size mark now becomes a half-inch mark, the eighth-inch

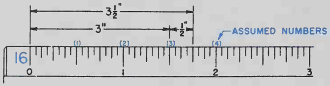


Fig. 7-2. Half-size, using the full-size scale.

now becomes a quarter, and so on with the sixteenth mark becoming an eighth. Let's see how well you can use this scale.

DRAFTING ACTIVITY

1. Measure the length of the lines in Fig. 7-3.
2. Note that the scale is indicated as half-size.
3. Record your readings on a sheet of paper.

For objects to be drawn QUARTER-SIZE, use the scale with the "3" marked on the end. In this scale the fine graduations 0 to 12 represent 1 ft. – 0 in. (or 12 in.), and you read the scale directly. A distance of 3 1/2 in. would be measured to the right of zero, as shown in Fig. 7-4.

To measure a distance of 1 ft. – 6 1/4 in., move your eyes to the left of zero to the 1 ft. mark, and this represents one point of your distance. Move your eyes to the right of zero until you come to 6 in. and to 1/4 in.; this represents the other point of your distance, Fig. 7-5.

Try your skill at measuring the lines assigned in the activity in the next column.

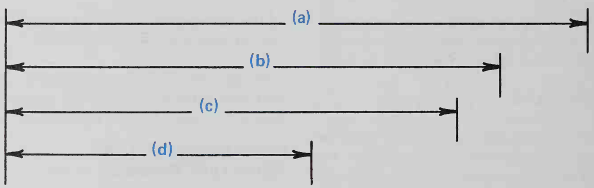
DRAFTING ACTIVITY

1. Measure the length of the lines in Fig. 7-6.
2. Record your readings on a sheet of paper.

Drawing an object to EIGHTH-SIZE is done in the same manner as the quarter-size, only the scale marked "1 1/2" is used and is found on the opposite end of the scale from the quarter-size scale.

Sometimes there is a need to enlarge certain parts of an object in order to clarify some detail. The scales marked with the "1 1/2" and the "3" can be used to enlarge or to reduce a drawing. When the drawing of an object is to be enlarged, one and one-half its actual size, the fine graduated section from 0 to 12 on the scale marked "1 1/2" now represents 1 in. (instead of 1 ft.), Fig. 7-7.

The full-size scale can also be used to enlarge by letting 2 in. on the scale represent 1 in. on the object.



HALF-SIZE SCALE

Fig. 7-3. Measuring problem.

DRAFTING ACTIVITY

Measure and dimension the splined joint, as shown in Fig. 7-8.

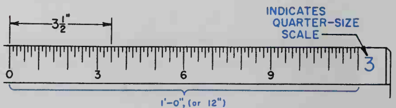


Fig. 7-4. Quarter-size scale.

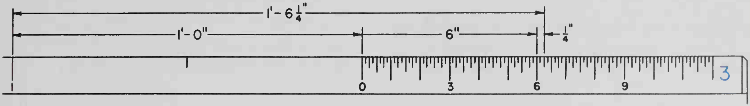


Fig. 7-5. Feet and inches on quarter-size scale.

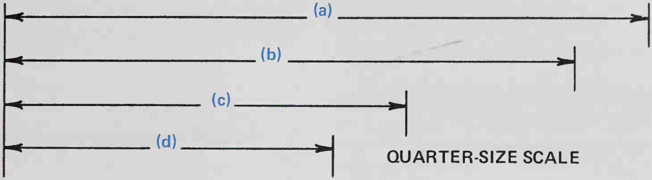


Fig. 7-6. Measuring problem.

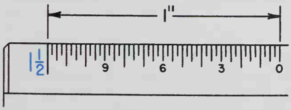


Fig. 7-7. Enlarging with the one and one-half scale.

Other scales on the architect's scale are: 1 in., 3/4 in., 1/2 in., 3/8 in., 1/4 in., 3/16 in., 1/8 in. and 3/32 in. These scales represent feet on a scaled drawing. For example, the scale marked 1/4 means 1/4 in. on the drawing represents 1 ft. – 0 in. on the actual size of the object. It would be indicated on the drawing like this:

SCALE — 1/4" = 1'-0"

This is the scale most frequently used in drawing house plans:

FLOOR PLAN
1/4" = 1'-0"

Ask your instructor or local building contractor to show you a set of architectural blue prints and check the scale on these.

Note the difference between the one-quarter scale and the quarter-size scale:

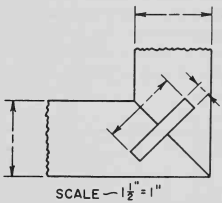


Fig. 7-8. Measuring problem.

One-quarter scale: 1/4 in. = 1 ft. - 0 in.
and is 1/48 actual size

Quarter-size scale: 3 in. = 1 ft. - 0 in.
and is 1/4 actual size

In Fig. 7-9 note how the scale is used to measure, or to lay off a distance.

The scale is truly a valuable device to you in making a drawing. You can enlarge a drawing two or

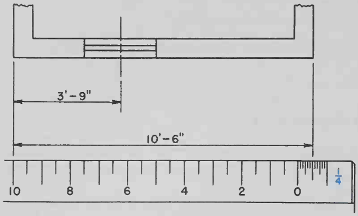


Fig. 7-9. Measuring with the one-quarter scale.

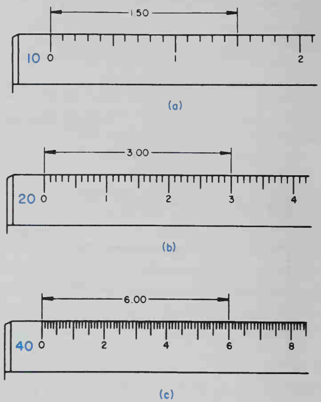


Fig. 7-11. Using the engineer's decimal scale for scale measurements.

three times, or let 1 in. on the scale represent 50 to 100 miles or more in drawing a map.

DRAFTING ACTIVITY

1. Measure the distance marked in Fig. 7-10.
2. Note the scale for each line.
3. Record your reading on a sheet of paper.

MEASURING WITH THE ENGINEER'S DECIMAL SCALE

The decimal scale is marked on the end of each scale indicating the number of divisions into which the inch has been divided, Fig. 7-11. A scale marked "10" indicates a division of 10 parts to the inch, "20" indicates 20 parts to the inch and so on. These divisions are helpful in laying off decimal measurements on the full-size scale. A measurement of 1.5 inches is shown in Fig. 7-11 (a). The "20" scale may be used as a half-size scale and each unit is subdivided into 10 parts. A measurement of 3 inches is shown on the half-size scale in Fig. 7-11 (b). The "40" scale is

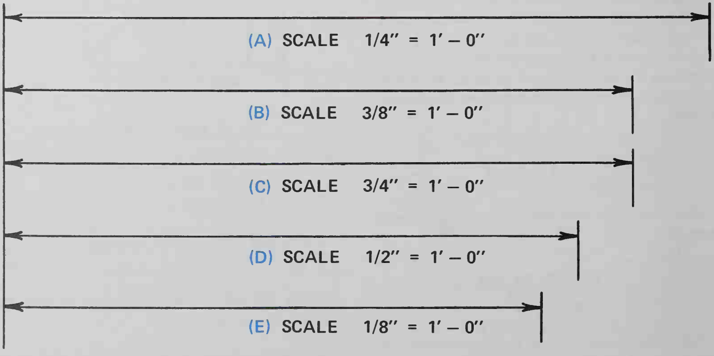


Fig. 7-10. Measuring problem.

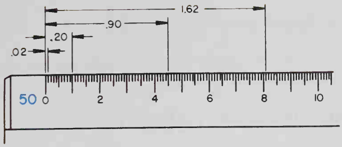


Fig. 7-12. Measuring with the "50" scale on the decimal scale.

divided into 40 parts to the inch and this scale may be used as a quarter-size scale by letting each unit of 10 equal an inch, Fig. 7-11 (c).

The "50" scale is divided into 50 parts to the inch and each division equals 1/50 or .02 inch, Fig. 7-12. This is the scale commonly used for full-size drawings of decimal-dimensioned machine parts. A measurement of 1.62 inches is shown in Fig. 7-12.

MEASURING WITH THE METRIC SCALE

The metre is the unit of measure in the metric

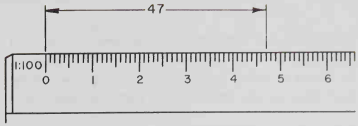


Fig. 7-13. Measuring with the metric scale.

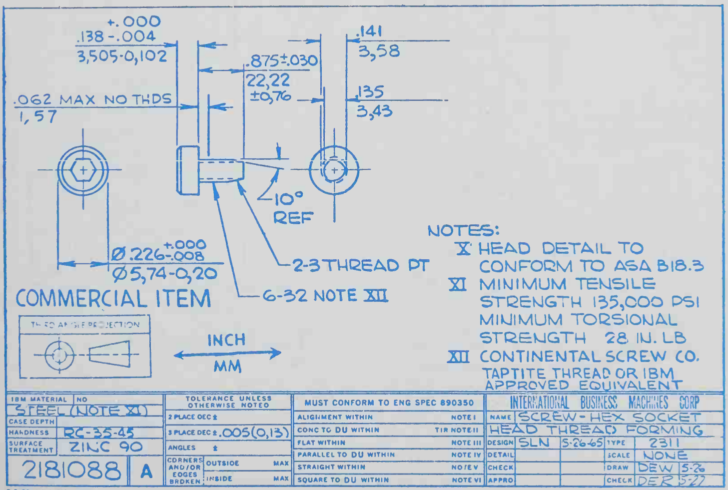
system. In Fig. 7-13, a scale of 1:100 means the scale is reduced one-hundredth size. The "1" (1 centimetre) on the scale represents 1 metre on the reduced scale of 1:100.

The metric scale also may be used as a full-size scale (1:1) by letting the "1" represent 1 centimetre (its actual size). The smallest division on the metric scale is 1 millimetre (one-tenth of a centimetre). A reading of 47 millimetres is shown in Fig. 7-13.

DUAL DIMENSIONING

A dual dimensioned drawing, using decimal inch

Fig. 7-14. A dual dimensioned drawing has both decimal inch and millimetre divisions. (IBM)



dimensions and millimetres, is shown in Fig. 7-14. Drawings which will be used in the United States and in countries using the metric system are sometimes dual dimensioned (using metric and inch dimensions).

TIPS ON MEASURING

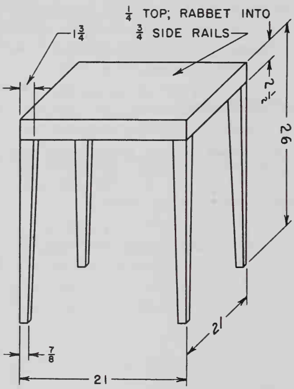
1. Keep the scale clean.
2. Eye the scale directly from above.
3. Use a sharp pencil.
4. Use the largest scale that will fit the paper.
5. Do not move the scale to make individual measurements when laying off a series of distances along a line.
6. Recheck measurements after laying off.

You should be able to measure distances with any of the scales quite easily now.

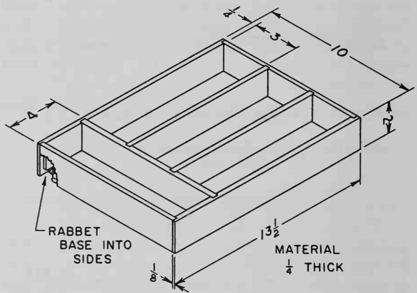
HOW TO CHECK YOUR DRAWING

Do you know that a few minutes spent in checking your drawing may result in a higher grade? Particularly is this true when you spot and correct errors and omissions! Use the following list in checking your drawing:

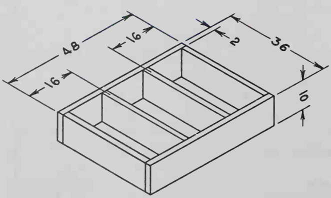
1. Are there MISSING LINES such as a short-object



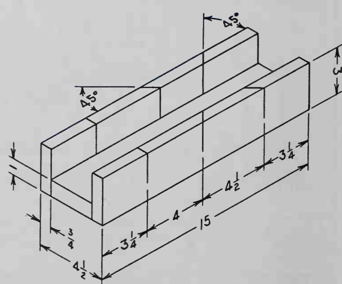
GAME TABLE



SILVERWARE TRAY



PLATFORM FRAME



MITRE BOX

Fig. 7-15. Problems for scale drawing. Dimensions are in inches.

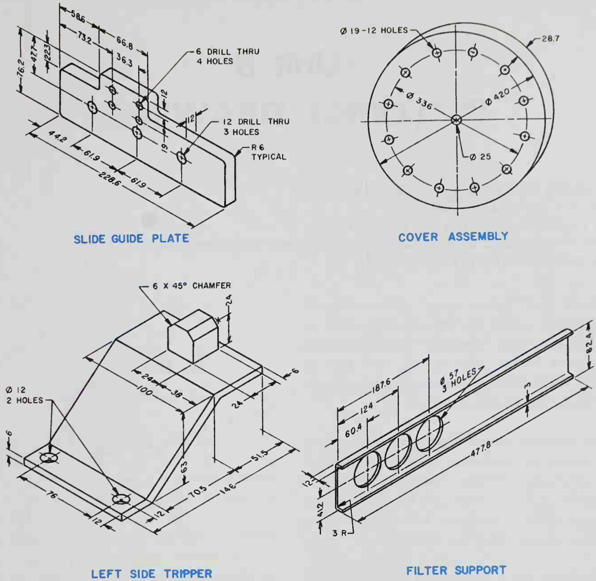


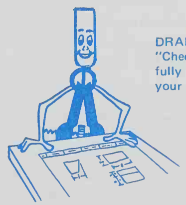
Fig. 7-16. Problems for scale drawing. Dimensions are in millimetres.

line, hidden line, center line, or dimension line?

2. Are there MISSING CIRCLES or ARCS?
3. Are CONSTRUCTION LINES too heavy?
4. Are CORNERS sharp and free from overlaps?
5. Have all NECESSARY DIMENSIONS been provided?
6. Are LETTERS, NUMERALS and ARROWHEADS properly formed?
7. Have all SHOP NOTES been included?
8. Is the TITLE BLOCK complete?
9. Are all LINES of the CORRECT WEIGHT?
10. Is your plate CLEAN and NEAT?

DRAFTING ACTIVITY

1. From the problems in Figs. 7-15 and 7-16, make scaled multiview drawings as assigned by your instructor.
2. Problems are to be dimensioned.
3. Check your drawings by the tenpoint check system.



DRAFTY SAYS:
"Check your drawing carefully before handing it to your instructor."

QUIZ – UNIT 7

1. What does drawing to scale mean?
2. What scales are commonly used in drafting today? How do they differ?
3. When should an object be drawn to a size smaller than actual size?
4. When should an object be drawn larger than actual size?
5. How many different scales are on the scale (instrument) you are using?

Unit 8
PICTORIAL DRAWINGS

After studying this unit, you will know:
1. **What are pictorial drawings.**
2. **How pictorial drawings are constructed.**
3. **When an isometric view should be drawn, and when an oblique view would be more satisfactory.**

You have been getting some experience with working drawings which you should find useful in your shop work. There is another kind of drawing you will want to be able to do, and that is PICTORIAL DRAWING. You constructed multiview drawings from pictorial drawings in Unit 3.

Pictorial drawings show several faces of an object in one view and are frequently used to supplement working drawings. Multiview drawings are best for showing details of construction, and for dimensioning purposes, but pictorial views are better for showing an object as it appears when you look at it.

There are two types of pictorial drawings which are commonly used in shop drawings – isometric and oblique. You will have an opportunity to learn how to draw these two types, and to learn something about a third type called perspective drawing.

ISOMETRIC DRAWING

Isometric drawing is a type of pictorial drawing that is used in making many shop drawings. It shows the object in one view rather than in several views.

ISO- is a prefix meaning EQUAL and METRIC means MEASURE, hence ISOMETRIC means EQUAL MEASURE. It means the object is positioned (revolved and tilted) so that the measurement in all three directions (height, width and depth) are made with the same scale, Fig. 8-1. The dark lines in Fig. 8-1 and all lines parallel to these lines are known as isometric lines. Horizontal lines in multiview drawings become 30 deg. lines in the isometric view, Fig. 8-2.

Vertical lines in multiviews remain vertical in the isometric view, Fig. 8-2. Let's see how an isometric drawing of the slotted block, Fig. 8-3 (a), is constructed.

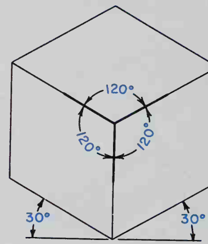


Fig. 8-1. Isometric axes.

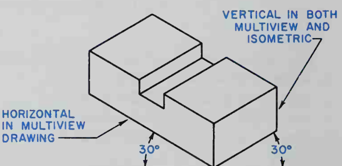


Fig. 8-2. Horizontal and vertical lines in isometric.

Procedure for constructing an isometric drawing:

1. Select the position of the object which will best describe its shape.
2. Start by laying out the axes for the lower corner, Fig. 8-3 (b).
3. Make over-all measurements in their true length on the isometric axes or lines parallel to the axes. Fig. 8-3 (c).
4. Construct a "box" to enclose the object, Fig. 8-3 (d).
5. Draw isometric lines of the object, Fig. 8-3 (e).

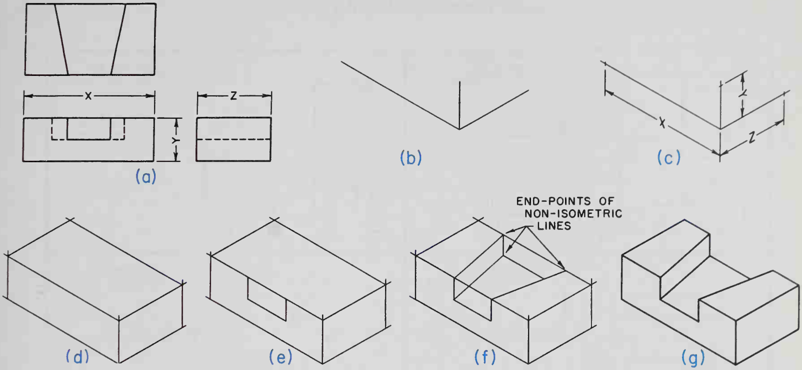


Fig. 8-3. Steps in constructing an isometric drawing.

6. Draw non-isometric lines (lines which are neither horizontal nor vertical in the multiview projection) by first locating the end points of these lines and then connecting the points by use of a straightedge, Fig. 8-3 (f).
7. Do not show hidden lines in isometric drawings; they are used only when clarity demands it.
8. Darken all object lines to complete the isometric drawing, Fig. 8-3 (g).

Isometric views may also be drawn as viewed from below the object. The isometric axes are then projected 30 deg. below horizontal as shown in Fig. 8-4.

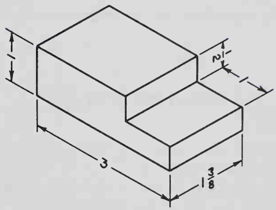


Fig. 8-5. Isometric dimensioning.

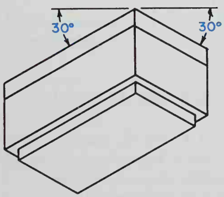
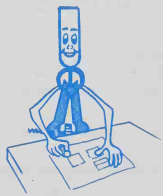


Fig. 8-4. Isometric drawing viewed from below the object.

DIMENSIONING ISOMETRIC DRAWINGS

Dimension lines are parallel to the isometric axes, and extension lines are projected in line with the surface or distance dimensioned, Fig. 8-5. Note that the dimension figures are also in line with the isometric axes.



DRAFTY SAYS: "Clean plate with soft vinyl if needed before final finishing lines."

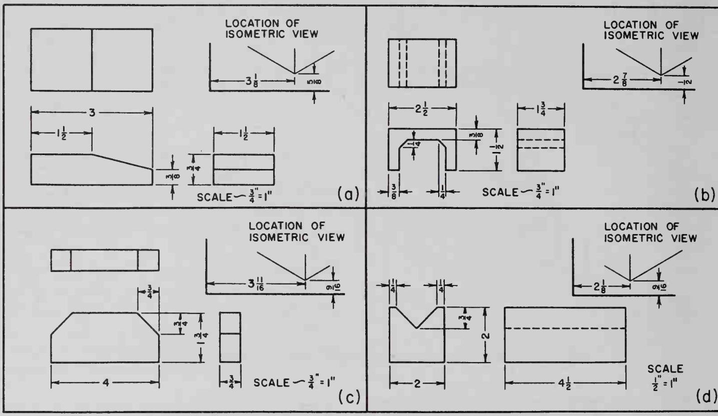


Fig. 8-6. Problems for isometric drawing.

DRAFTING ACTIVITY

1. Divide your plate into four sections using the Plan A layout.
2. Use sections A and B and draw isometric views of two of the objects shown in Fig. 8-6, as assigned by your instructor.
3. Note the suggested location of the isometric axes for each. Use the full-size scale to locate the isometric axes, but use the scale indicated for drawing the isometric view.
4. Dimension the drawings.

ISOMETRIC CIRCLES AND ARCS

Because isometric surfaces are viewed at an angle, circles and arcs are not true. They are more elliptical in shape. Let's find out how they are drawn.

Procedure for drawing isometric circles and arcs:*

1. Locate and draw the center lines of the circle, Fig. 8-7 (a).
2. From the point of intersection of the center lines, measure the radii (plural form of radius), Fig. 8-7 (b).
3. From these radius points, draw construction lines which are perpendicular (90 deg.) to the other center line, Fig. 8-7 (c) and (d).
4. The intersections of these lines are the four centers for the isometric circle or ellipse, Fig. 8-7 (e).
5. Draw the isometric circle as shown in Fig. 8-7 (f). Circles in all three isometric planes are shown in Fig. 8-7 (g).
6. Draw arcs in the same manner as circles, using only the portion of the circle required, Fig. 8-7 (h).

*Courtesy A. Frank Nelson

DRAFTING ACTIVITY

1. In sections C and D, draw the isometric views of two of the problems shown in Fig. 8-8, as assigned by your instructor.
2. Dimension the drawings.

HOW TO CENTER AN ISOMETRIC DRAWING

In the isometric problems just completed, the suggested location of each problem on a sheet was given. It is a simple matter to locate other isometric

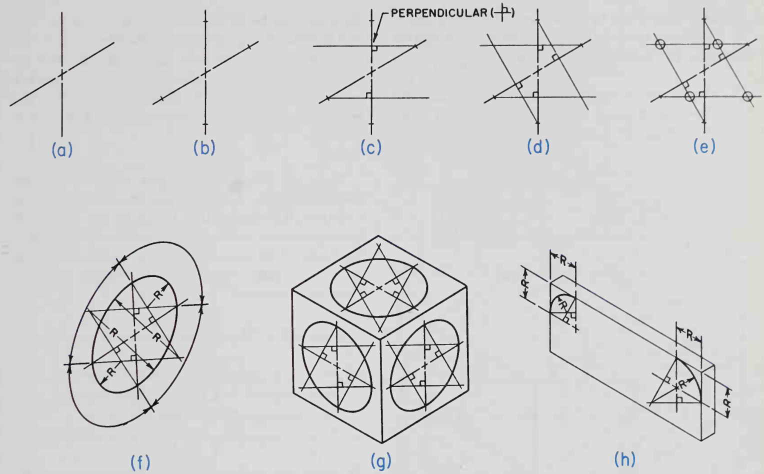


Fig. 8-7. Steps in drawing isometric circles and arcs.

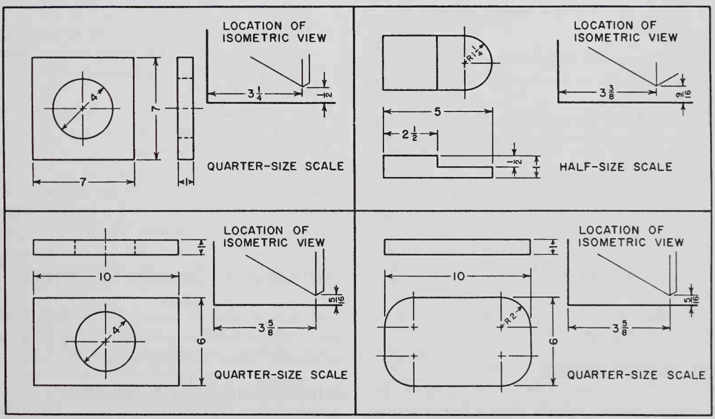


Fig. 8-8. Isometric circle and arc problems.

problems on a sheet by locating the isometric center of the object and positioning this point in the desired location. The procedure is as follows:

1. Select the desired location for centering the isometric drawing (usually the center of a sheet or other space), Fig. 8-9.

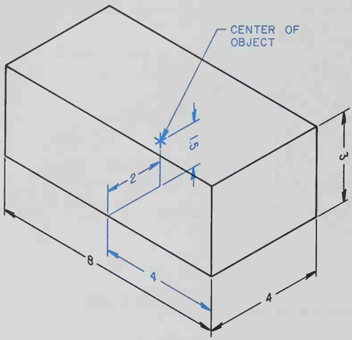


Fig. 8-9. Centering an isometric drawing.

2. From this point, measure down vertically one-half the height of the object (1.5 inches in our illustration).
3. On a 30 deg. isometric line to the left, measure one-half the depth of the object (2 inches in our illustration).
4. On a 30 deg. isometric line to the right, measure one-half the width of the object (4 inches) to locate the starting point of the isometric drawing to be centered in a desired location.

DRAFTING ACTIVITY

Locate on the sheet and draw the problems in Fig. 8-10 as assigned by your instructor.

OBLIQUE DRAWINGS

Another type of pictorial drawing used in drafting is the oblique drawing. It has a front surface which is shown in its true size and shape, and a top and a side which usually slant back at an angle of 45 deg., but the angle can be 30 deg. or 60 deg., Fig. 8-11. This SLANTING of the top and side, back from the front, is the meaning of the term OBLIQUE. This type of drawing is particularly useful when circles or arcs are to be shown and can be drawn in a front surface where they appear as true arcs or circles, rather than ellipses.

When the depth of the object, shown in the top and side surfaces, is true length, the drawing is called a CAVALIER OBLIQUE, Fig. 8-12 (a). This true length produces an object that appears unnatural, and the depth is sometimes foreshortened to one-half of its true length. This type of drawing is called CABINET OBLIQUE, Fig. 8-12 (b).

Procedure for constructing an oblique drawing:

1. Select the surface to be shown in the front face. Give consideration first to circles and arcs, next to long rectangular surfaces, Fig. 8-13.
2. Draw front view in its true size and shape, Fig. 8-14 (a).
3. Draw oblique lines (usually 45 deg.) to the right to form the top and right surfaces, Fig. 8-14 (b), or to the left for top and left surfaces, Fig. 8-14 (c).
4. Measure the depth on an oblique line, and "box" in the top and side surfaces, Fig. 8-14 (d).
5. Draw lines which are not parallel to the oblique axes by locating the end points (as in isometric drawing) and connecting these points by use of a straightedge, Fig. 8-14 (e).
6. Do not show hidden lines in oblique drawings unless they are needed for clarity.
7. Darken all lines, Fig. 8-14 (f).

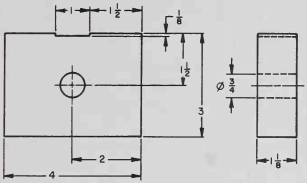
Oblique views may also be drawn as viewed from below the object. To do this, project the oblique lines downward from the front view, Fig. 8-15.

DIMENSIONING OBLIQUE DRAWINGS

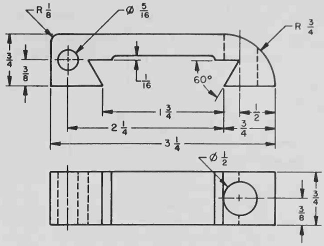
Dimension lines are parallel to the oblique axes and extension lines are projected in line with the surface or distance dimensioned, Fig. 8-16.

CIRCLES AND ARCS IN OBLIQUE

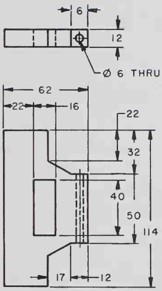
Since the front of an oblique drawing is a true view, as in a multiview drawing, all circles and arcs appear in their true shape.



WORK TABLE GIB

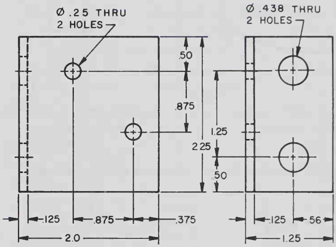


CROSS FEED STOP

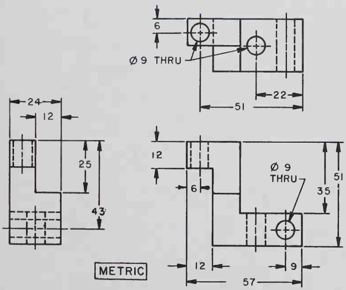


METRIC

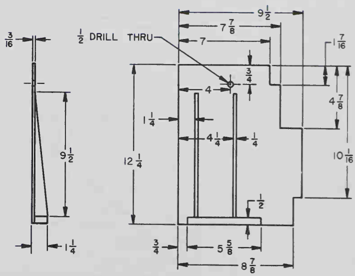
GRIP-HOOD LATCH



CONTROL VALVE BRACKET



LEFT "Z" AXIS SUPPORT



COVER

Fig. 8-10. Additional isometric problems.

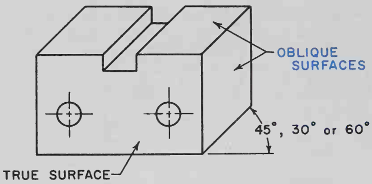


Fig. 8-11. Oblique drawing.

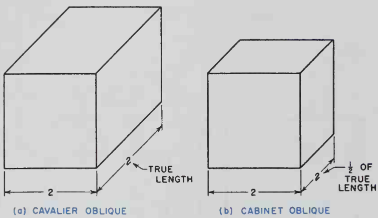


Fig. 8-12. Cavalier oblique and cabinet oblique drawings.

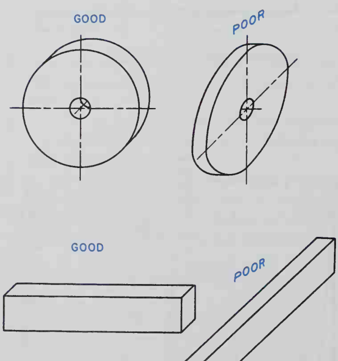


Fig. 8-13. Selection of the front surface in oblique drawings.

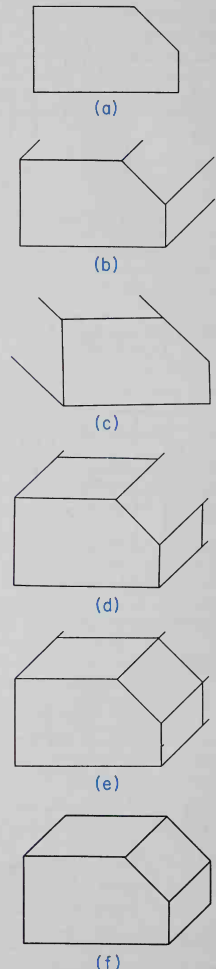


Fig. 8-14. Steps in constructing an oblique drawing.

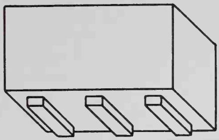


Fig. 8-15. Oblique drawing viewed from below the object.

To draw circles and arcs on oblique surfaces, follow the same procedure as given for drawing these in isometric views, Fig. 8-7. Only the angle of the center lines differs.

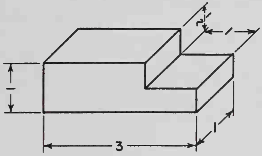
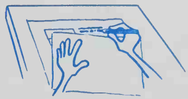


Fig. 8-16. Oblique dimensioning.



DRAFTY SAYS: "When lettering, protect drawing with extra sheet of paper."

DRAFTING ACTIVITY

1. In sections A and B, draw oblique views of two of the problems shown in Fig. 8-17, as assigned by your instructor.
2. Locate the oblique drawings in the same

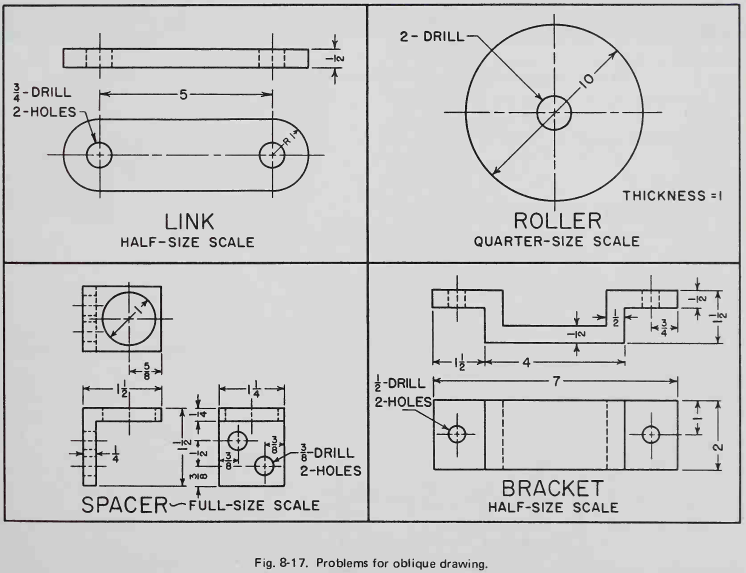


Fig. 8-17. Problems for oblique drawing.

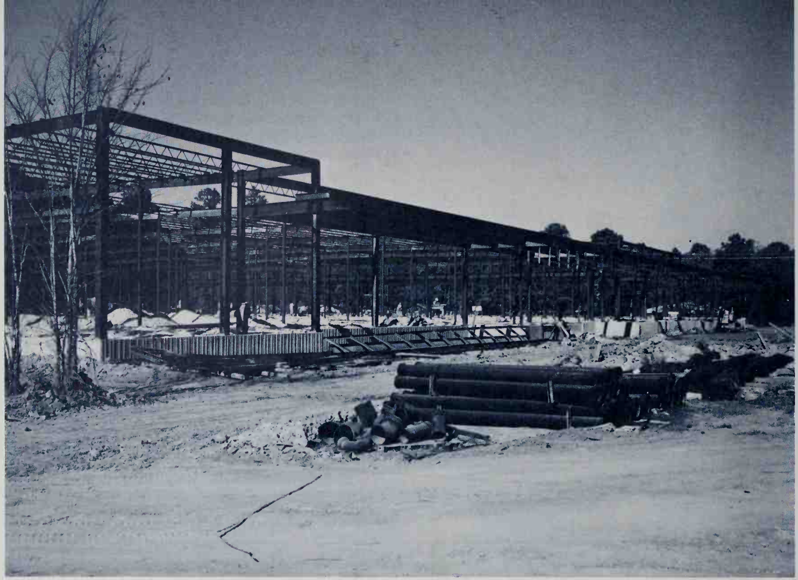


Fig. 8-18. Lines tend to converge at vanishing points in this photo of a construction project.

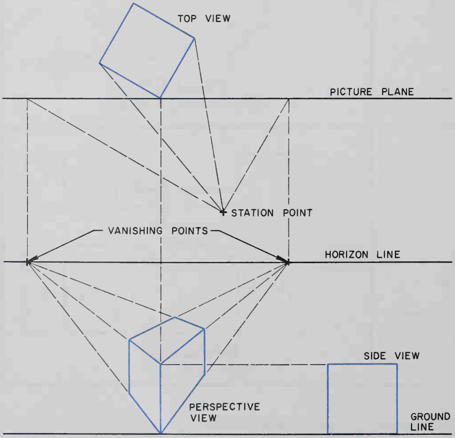


Fig. 8-19. Horizontal lines in a perspective drawing tend to meet at the horizon.

manner as described in Fig. 8-9 for isometric drawings. The only difference is in the angle of the oblique lines.

3. Dimension the drawings.

PERSPECTIVE DRAWINGS

In a photograph, lines tend to converge at vanishing points giving a perspective view of the object, as shown in Fig. 8-18.

The perspective drawing is a third type of pictorial drawing. Like the photograph, it is more natural in its appearance than either the isometric or oblique drawings. The receding lines tend to meet at vanishing points on the horizon rather than remain parallel as in the other pictorial drawings, Fig. 8-19. The procedure for constructing a mechanical perspective with ordinary drafting equipment is lengthy and beyond the scope of this text. However, there are perspective drawing boards and equipment available today which produce mechanically accurate perspectives and are relatively easy to use, as shown in Fig. 8-20. Perhaps your instructor has one of these and can demonstrate its use.

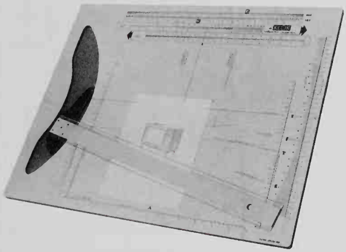


Fig. 8-20. The Klok perspective drawing board.

For illustrating the different types of pictorial drawings, the jewel box is shown in four pictorial views, Fig. 8-21.

DRAFTING ACTIVITY

1. In sections C and D, draw additional isometric or oblique drawings as assigned by your instructor from the problems shown in Fig. 8-22.
2. Estimate the location of the axes so as to approximately center each drawing.

QUIZ – UNIT 8

1. What are the common types of pictorial drawings?
2. For what purposes are pictorial drawings used?
3. What angle is used for horizontal lines in isometric drawings? In oblique?
4. How does the cabinet oblique differ from the cavalier oblique drawing?
5. How are isometric and oblique drawings dimensioned?

NEW WORDS FOR YOU TO USE

1. Isometric (i-so-met'rik)
2. Oblique (o-blek')
3. Perspective (per-spek'tiv)
4. Ellipse (e-lips')

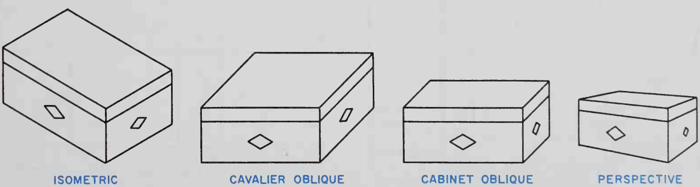
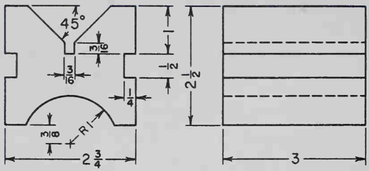
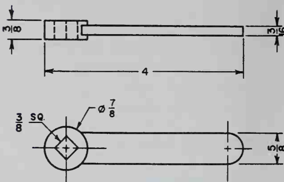


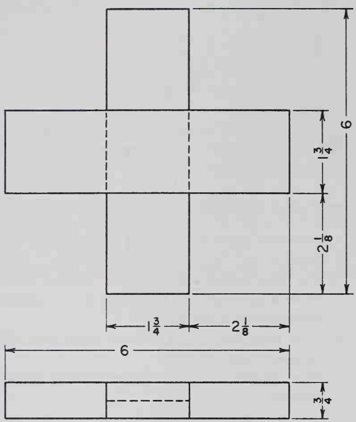
Fig. 8-21. Jewel box in four pictorial views.



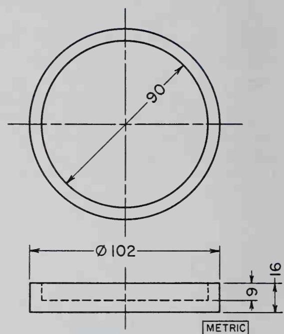
V BLOCK



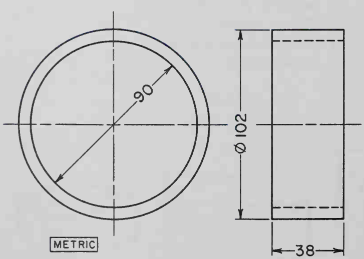
LATHE WRENCH



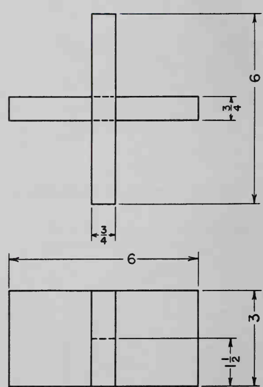
FLAT CROSS-LAP JOINT



BASE CAP

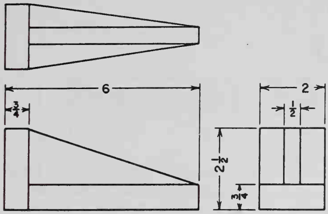


STEEL COLLAR

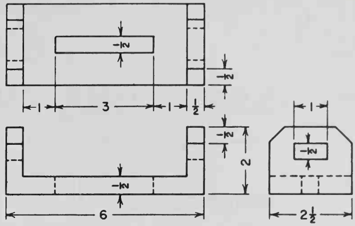


EDGE CROSS-LAP JOINT

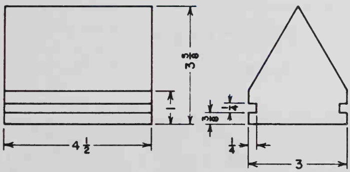
Fig. 8-22. Problems for isometric or oblique drawing.



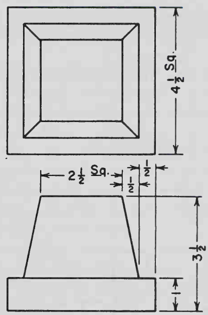
ANGLE BLOCK



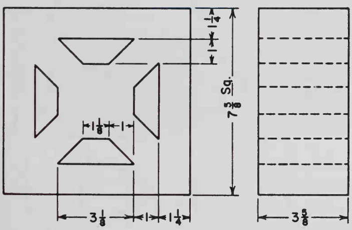
SLIDING CLAMP



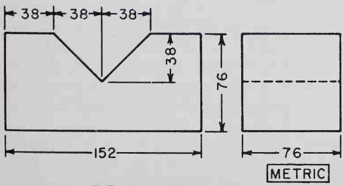
WEDGE



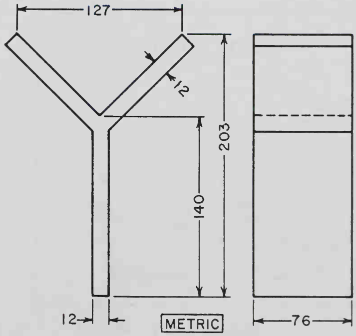
PILLAR BLOCK



ORNAMENTAL BLOCK

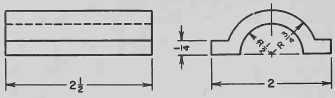


DRILL BLOCK

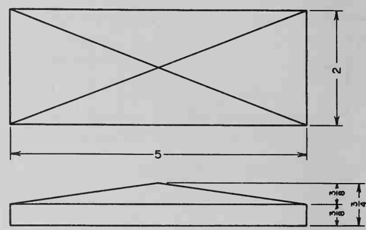


Y-SUPPORT

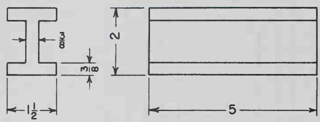
Fig. 8-22. (Continued.) Additional problems for isometric or oblique drawing.



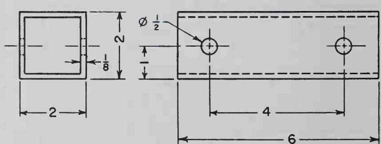
COVER PLATE



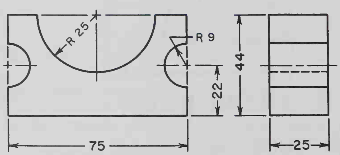
PAPER WEIGHT



I-BEAM

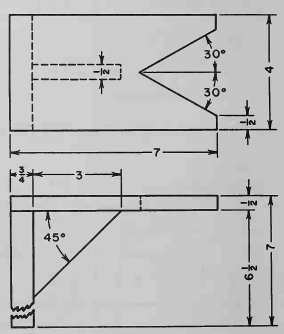


SHAFT CONNECTOR

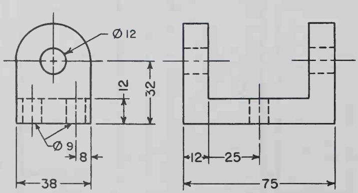


METRIC

GUIDE BLOCK



COPING-SAW REST



BRACKET

METRIC

Fig. 8-22. (Continued.) Additional problems for isometric or oblique drawing.

Unit 9

PROBLEM SOLVING AND DESIGN

After studying this unit, you will know:
1. **What is problem solving.**
2. **What is design drafting.**
3. **What steps are involved in problem solving.**

Problem solving is the finding or creating of solutions to any problem or task that needs to be done, Fig. 9-1. Design is a type of problem solving in which the task involves the visual presentation of the solution through a freehand sketch or instrument drawing. Problems like redesigning your room for a better study area or storage of hobby items; designing an improved way to carry your bicycle on the family car; developing a "secret storage compartment" for the protection of valuables around the house; or laying out and developing a home workshop, are typical of those we need to solve every day.

Fig. 9-1. It is the job of these industrial designers and engineers to develop solutions to the problems of manufacturing. (Anderson Engineering Div.)

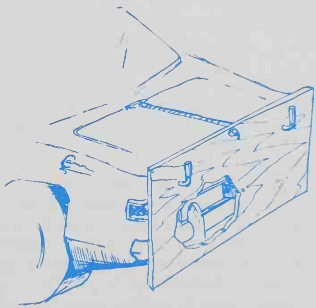
Instead of just beginning on a solution, problem solving involves "thinking" through several possible solutions. Your skills and knowledge in drafting will help you arrive at the best of several alternatives. Follow the steps of procedure listed below and you will find this method easy and very helpful. This is a typical example of design problem solving.

1. Identify the problem.

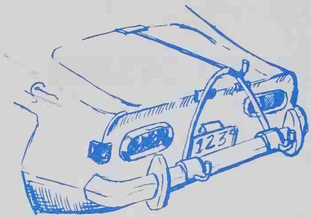
   To design and construct a device to fasten a bicycle to the family car for transportation.
2. State the facts or conditions.

   Must permit easy and quick attachment and release without damage to car or bicycle. Cost of materials not to exceed a specified amount.
3. Mentally develop possible solutions — consider and sketch several ideas:
   a. Rack made of wood to drop over bumper and bumper guards, padded slots for bicycle to slip into.

      Factors: heavy, cumbersome to store when not in use, cost would exceed allotted amount.

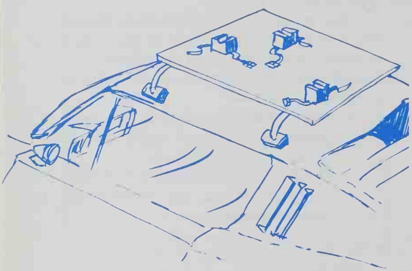


   b. Rack made of conduit or pipe, to be clamped to bumper and trunk lid, pads



to which frame and front wheel are clamped.
Factors: light weight, could be neat in appearance, clamping devices would need to be simple, cost could be kept within allotted amount.

c. Car-top carrier with platform, pads and



clamps for bicycle.
Factors: difficult to attach, difficult to load bicycle, and cost would exceed amount allotted.

d. (Other solutions could be developed and explored.)

4. Select best solution.

Number 3 (b) was selected as most feasible. A working drawing was made and the rack constructed. If this problem involved the making of a quantity of these racks, a model or prototype could be developed for further study and improvement in design.

5. Application and follow-up.

Does it meet the objectives of ease of fastening, safety, damage free and cost? If it does, you have found a satisfactory solution to a problem, if not, add what information you gained and repeat steps 2 thru 5 again with another possible solution.

This method of problem solving will help you arrive at the best solution of problems. Your experience in drafting and laboratory work will help you in developing the solution and final product.

Design and problem solving are creative processes. The more knowledgeable you are on the subject of the problem to be solved and related subjects, the better your chances are of developing satisfactory solutions. You will have an opportunity in the remaining units of this text to gain experiences in design and problem solving.

DESIGN AND PROBLEM SOLVING ACTIVITY

Select a problem from the list that follows and develop several possible solutions through the problem solving process discussed in this unit. Prepare a freehand sketch of the best possible solution and have your instructor check the suggested solution and its design. Prepare a working drawing of the design selected.

1. A portable container for hand tools you frequently need in doing jobs around your home. Container should provide for organization of the tools so they are readily available and for the protection of edge tools.
2. A home workshop area and tool storage to enable you to practice your hobby or to do home maintenance repairs. Tools should be stored in a manner so they are easily located when needed and the work area should accommodate the usual type jobs performed.
3. A container to hold your hobby collection and permit its display. The size of the container should be in keeping with its surroundings and storage space when not in use. The cost should be reasonable and within your ability to finance.
4. A new design for a carrying device on your bicycle. The design should meet your needs to carry certain items on your bicycle.
5. Or, select a problem of your own and for which you desire a solution.

Your instructor may assign two or more students to work on the same problems. In this way, more ideas are brought to bear on the problem solving process.

Unit 10
ELECTRICAL DRAFTING

After studying this unit, you will know:
1. **What types of drawings are used in the field of electricity.**
2. **How electrical diagrams are drawn.**
3. **What symbols are used in electrical diagrams.**

Electrical devices and circuits, such as the transitor radio shown in Fig. 10-1, would be difficult to draw as pictorial or multiview drawings. Instead, electrical diagrams are used more often in constructing radios, hi-fi equipment, electric motors, and other electrical projects. The use of these diagrams speeds up electrical drafting and makes the reading of these drawings much easier.

Fig. 10-1. A transistor radio. For various diagrams of this radio circuit, see Figs. 10-6 and 10-7.

The purpose of this unit in electrical drafting is to acquaint you with the types of electrical circuits and the techniques of drawing electrical diagrams. The skill and knowledge needed in electrical drafting is not so much in the area of drafting as it is in the understanding of electricity. Your study of electrical drafting will help you in your understanding of electricity, and a study of electricity will bring more meaning to your work in electrical drafting.

TYPES OF CIRCUITS

A circuit is a path along which the electric current flows from the negative side of the power source through the circuit and on to the positive side of the power source, completing the circuit. There are three types of electrical circuits which may be used when two or more devices or controls are to be placed in the circuit. Common circuits are the SERIES circuit, PARALLEL circuit and combinations of these two circuits.

The series circuit provides a single, continuous path in which the current flows. The electrical devices in a series circuit are connected one after another and the current flows through the first device, through the second, and so on until it returns to the power source. A string of lights (a type of resistor) wired in series is shown in Fig. 10-2 (a). Some Christmas tree lights are wired in series. In this type of circuit, when one light burns out, the remaining lights will not burn, because the circuit is broken.

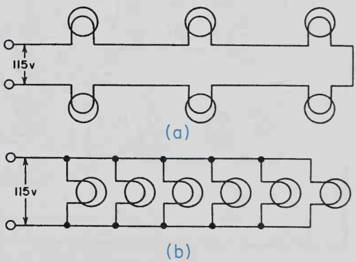


Fig. 10-2. Lights in series (a) and in parallel (b).

In the parallel circuit, the current has two or more paths to follow. Each device in a parallel circuit has access to the power source and, therefore, will continue to operate regardless of failure in another device. A string of lights wired in parallel is shown in Fig. 10-2 (b). More expensive Christmas tree lights are wired in this manner. Parallel circuits are used in house wiring.

A combination circuit of resistors in series and parallel is illustrated in Fig. 10-3. Note the two resistors in "series" at the top and bottom of the circuit drawing, while the two resistors at left branch off in "parallel."

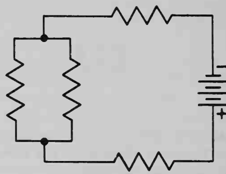


Fig. 10-3. A combination circuit of resistors in series and parallel.

TYPES OF ELECTRICAL DIAGRAMS

WIRING DIAGRAMS are pictorial drawings of electrical assemblies showing how the various parts are arranged and connected together, Fig. 10-4. This type of diagram is used by hobbyists and electrical repairmen to install and service electrical devices. Electrical diagrams for houses are a form of wiring diagrams, Fig. 10-5.

SCHEMATIC DIAGRAMS are similar to wiring diagrams, except electrical symbols instead of pic-

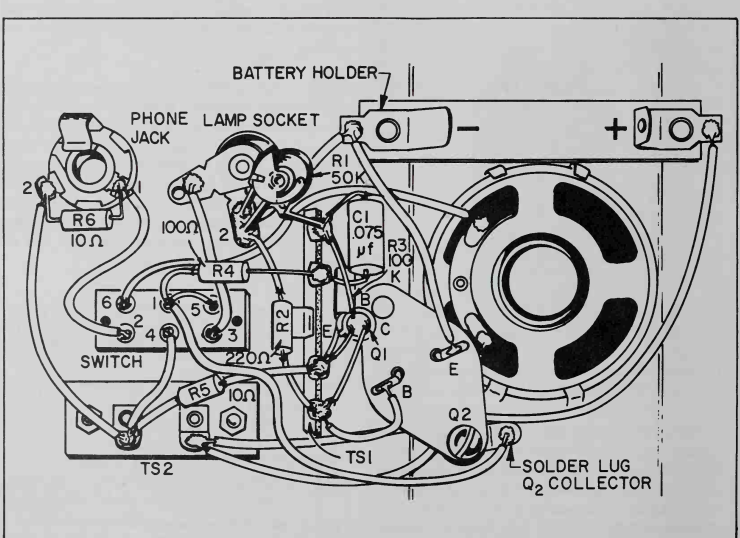


Fig. 10-4. Wiring diagram of a code oscillator.

tures are used for representing parts, Fig. 10-6. Schematic diagrams are used to show the functional relationship of electrical parts to each other and to the entire circuit. They do not show the location of parts or wiring connections as do wiring diagrams.

BLOCK DIAGRAMS are another type of electrical drawing. They show the relationship of the various

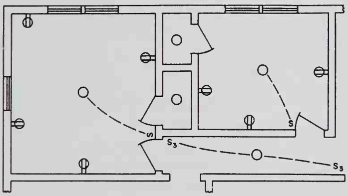


Fig. 10-5. House wiring diagram.

circuits within an electrical device, such as the transistor radio receiver in Fig. 10-7. Such a drawing may be used as a simplified drawing of complex electrical parts to show the function of the various sections, and for trouble shooting. The more complex the circuit, the more useful the block diagram. A block diagram of a superheterodyne receiver is shown in Fig. 10-8.

You will appreciate the uses of each of these electrical drawings as your knowledge of electricity and electronics increases.

HOUSE WIRING

The electrical diagrams on house plans are usually included on a scale drawing of the floor plan, as in Fig. 10-5. See Fig. 12-9, page 103, for electrical symbols used in house wiring. In planning the wiring for a house, attention should be given to the following: (1) location of switches near doorways, halls, stairways and other convenient places; (2) location of ceiling outlets where desired in rooms, closets, halls and stairwells; (3) location of convenience outlets on walls for table lamps, radios, television, clocks, kitchen appliances, shop equipment, etc. Lines are drawn from switches to the

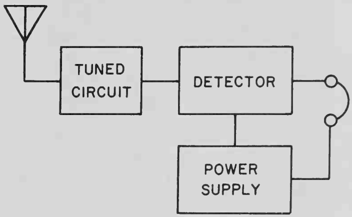


Fig. 10-7. Block diagram of the transistor radio, Fig. 10-1.

outlets they control, but other circuits are planned by the electrical contractor. The number of switches, outlets, etc., can be counted directly, and the amount of wire needed can be estimated from the location of the various devices on the scale drawing.

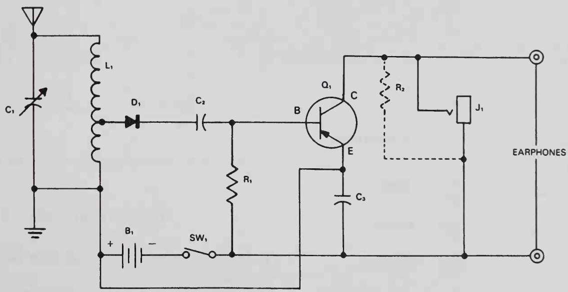


Fig. 10-6. Schematic diagram of the transistor radio shown in Fig. 10-1.

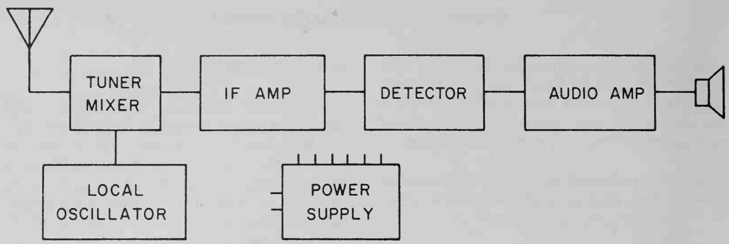


Fig. 10-8. Block diagram of a superheterodyne radio commonly found in automobiles and sound systems in TV sets.

DRAWING ELECTRICAL DIAGRAMS

Unlike other types of drawing you have been doing, electrical diagrams are not drawn to any particular scale. The diagram should be large enough to show clearly the various parts, and no larger. The symbols themselves may vary in size, but they should be drawn correctly and in proportion, Fig. 10-9. All lines are drawn about the weight of visible object lines, except when some part is to be emphasized, and then a heavier line is used.

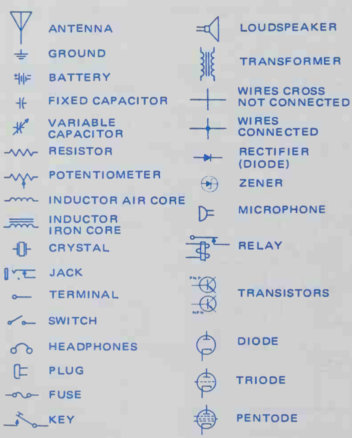


Fig. 10-9. Electrical symbols.

DRAFTING ACTIVITY

No. 1

1. Use the Plan A plate layout and draw as many of the electrical symbols, Fig. 12-9, and the electrical symbols, Fig. 10-9, as space will permit.

No. 2

1. Draw a wiring diagram for a light controlled by two 3-way switches. See Fig. 12-9, page 103 for proper symbols.
2. Place on a full-sized sheet, using the Plan A plate layout.

No. 3

1. If you have had instruction in electronics, try your skill at drawing a wiring diagram of the power supply illustrated by the schematic diagram, Fig. 10-10.

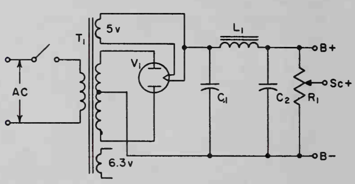


Fig. 10-10. Schematic diagram of a power supply.

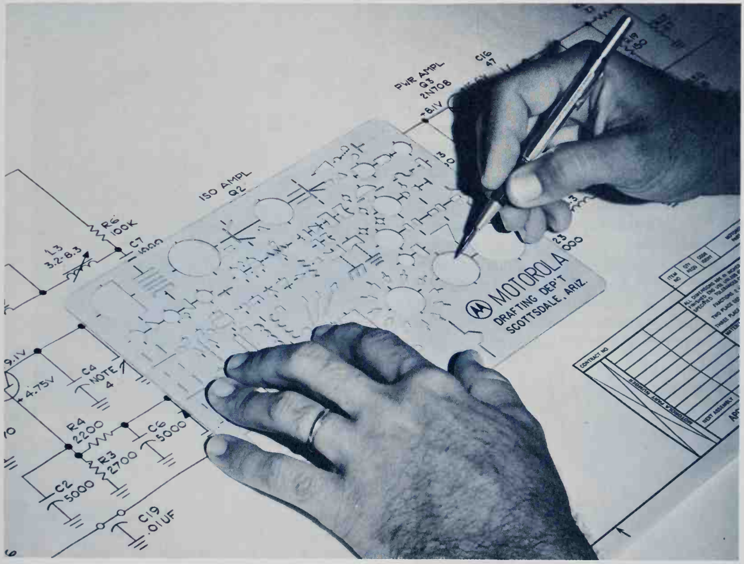
QUIZ – UNIT 10

1. How do the series circuit and the parallel circuit differ?
2. What are the three types of electrical diagrams and how do they differ?

3. What is the purpose of each type of electrical diagram?
4. What type of electrical diagram is most useful in trouble shooting?
5. Electrical diagrams on house plans are known as what type of electrical diagrams?
6. What should electrical diagrams for house wiring include?
7. How large should electrical symbols be drawn? What line weight should be used?

NEW WORDS FOR YOU TO USE

1. Series (ser'ez)
2. Circuit (sur'kit)
3. Diagram (di'a-gram)
4. Schematic (ske-mat'ik)
5. Superheterodyne (su-per-het'er-o-din)
6. Transistor (tran-sis'-tor)



Drafter using an electronic symbol template. (Motorola)

Unit 11

SURFACE DEVELOPMENT DRAFTING

After studying this unit, you will know:
1. What is a "stretchout."
2. How sheet metal patterns are developed.
3. How to use sheet metal drafting.

Surface development drafting is used in the layout of patterns for sheet metal ducts for air conditioning and heating systems, Fig. 11-1, and for package designs, Fig. 11-2. Surface development drafting is also used in laying out patterns for large storage tanks, Fig. 11-3.

The purpose of surface development drafting is to prepare full-size patterns or "stretchouts" to be used on flat sheet stock. In your shop or laboratory activities, you will be constructing projects of paper or sheet metal and a knowledge of surface development drafting will be useful. Let's see how patterns are developed for a rectangular box, a prismatic container, a truncated cylinder and a cone.

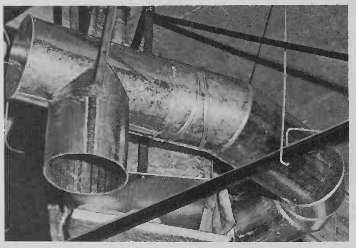


Fig. 11-1. Sheet metal ducts. (Lennox Industries, Inc.)

Fig. 11-2. Package design makes use of surface development drafting. (Packaging Corp. of America)

RECTANGULAR LAYOUTS

One of the simplest patterns to develop is the rectangular box. A layout for a rectangular box such as a pan or a radio chassis is developed as follows:

1. Draw the bottom of the pan (or top of radio chassis), Fig. 11-4 (a).
2. Add to each edge the height of the sides, Fig. 11-4 (b).
3. Add material for hems and seams if needed, Fig. 11-4 (c).
4. Cut out the pattern, then fold, and assemble with cellophane tape as a paper model; or transfer to metal, cut out, fold and assemble, Fig. 11-4 (d).

DRAFTING ACTIVITY

1. Develop the pattern for the radio chassis as shown in Fig. 11-5.
2. Letter your name on the top of the chassis pattern.

Fig. 11-3. A storage tank at an oil refinery.
(Mobil Oil Corp.)

3. Cut out and fold to shape.
4. Material could be added to close the ends, if desired.

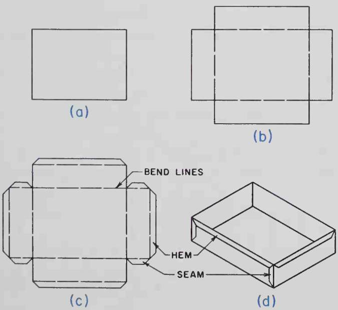


Fig. 11-4. Steps in laying out a rectangular pattern.

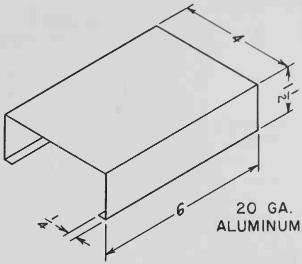


Fig. 11-5. Radio chassis.

LAYOUT FOR A PRISMATIC CONTAINER

A prism is a solid object with parallel sides and bases which are identical, such as the hexagonal prism (a) and the octagonal prism (b) shown in Fig. 11-6. A prismatic container is an enclosed object in the shape of a prism.

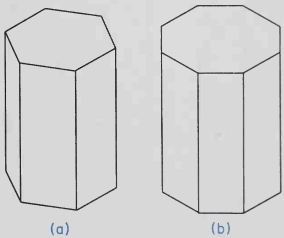


Fig. 11-6. Hexagonal and octagonal prisms.

The layout for a prismatic container is as follows:

1. Draw the hexagon (or octagon) near one edge of your layout sheet, Fig. 11-7 (a). (See pages 61 and 62 on the construction of polygons).
2. Draw lines representing the height of the prism, Fig. 11-7 (b).
3. Lay off the distances for the sides with dividers, Fig. 11-7 (c).
4. Draw the other base, Fig. 11-7 (d).

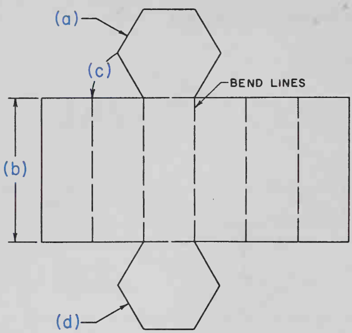


Fig. 11-7. Layout for a prismatic container.

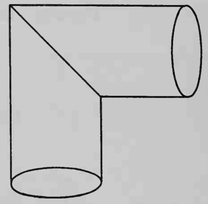


Fig. 11-8. Sheet metal elbow.

5. Add to layout for seams if necessary.
6. Cut out pattern, then fold and assemble with cellophane tape; or transfer to sheet metal; cut out, fold and assemble.

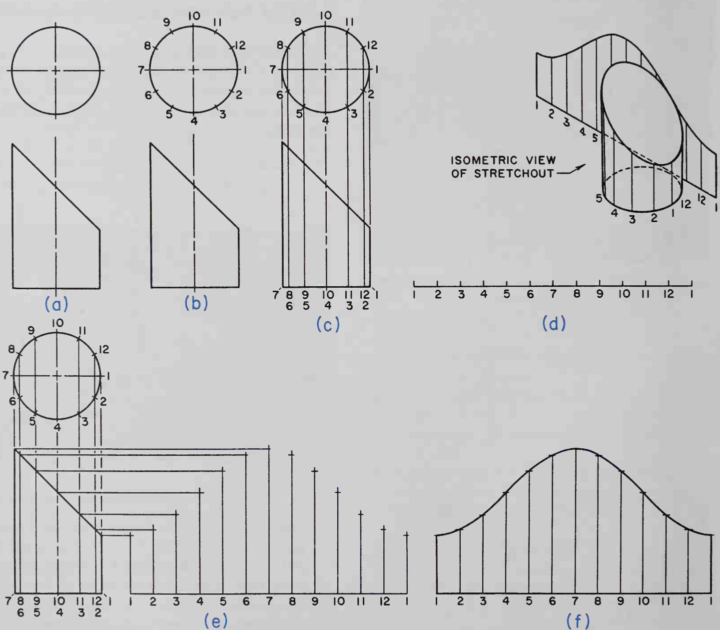


Fig. 11-9. Layout for a truncated cylinder.

DRAFTING ACTIVITY

1. Develop the pattern for the hexagonal or the octagonal prismatic containers, shown in Fig. 11-6.
2. Dimensions of the prisms are: 1 1/2 in. across the flat sides of the hexagon and octagon; 2 1/2 in. in height.
3. Letter your name on one side of the container.
4. Cut out and assemble with cellophane tape.

LAYOUT FOR A TRUNCATED CYLINDER

Have you noticed all of the twists and turns in the pipes of a hot-air furnace? Such pipes, which are cut off at an angle, or TRUNCATED, are called elbows when joined, Fig. 11-8. Do you wonder how it is possible to cut the pipe at just the proper angle to make it fit? The secret of this layout is not difficult if you follow this procedure:

1. Observe first, the isometric view of the layout (called stretchout) in the upper right-hand corner of Fig. 11-9.
2. Draw the top and front view as shown in Fig. 11-9 (a).
3. Divide the circular (top) view into a number of equal parts, say 12, Fig. 11-9 (b).
4. Project these points to the front view, Fig. 11-9 (c).
5. Draw the stretchout line 1-1 and step off on line 1-1, the 12 distances in the top view with dividers, Fig. 11-9 (d). This should equal the circumference of the cylinder.
6. Project perpendiculars up from these points, Fig. 11-9 (e).
7. Project the height of each line in the front view to the stretchout. Note that two lines are represented in the stretchout by one line in the front view, Fig. 11-9 (e).
8. Sketch a light curve first, and then, using the French curve, join these points with a smooth curve, Fig. 11-9 (f).
9. Add material for seams if needed.

If you have studied Unit 5, you have already had some experience with auxiliary views. The auxiliary surface of the truncated cylinder is developed as follows:

1. Construct the auxiliary center line 1-7 parallel to the inclined surface, Fig. 11-10.
2. Project the points which divide the circle into equal parts from the inclined surface to the auxiliary view.
3. Transfer the widths from the top view to the auxiliary, using the dividers.
4. Sketch a light curve through these points. Finish with the French curve.
5. Cut out and assemble pieces; or transfer to metal, cut out and assemble.

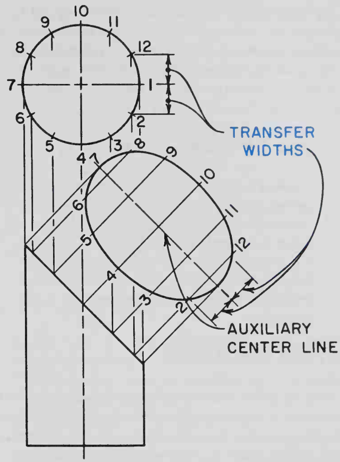


Fig. 11-10. Development of auxiliary surface.

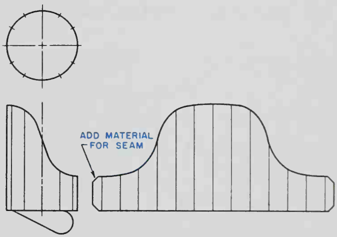


Fig. 11-11. Sugar scoop.

By omitting the auxiliary cap and laying out two pipe sections, with a 45 deg. cut, (the second section could be traced from the first) a right-elbow pipe joint could be formed, Fig. 11-8. This method of cylindrical development can be used also in laying out a sugar scoop, Fig. 11-11.

DRAFTING ACTIVITY

1. Develop a pattern for the truncated cylinder in Fig. 11-12.
2. Letter your name on the cylinder.
3. Trace a second section from the first, cut out and assemble as a right-elbow pipe; or develop the auxiliary cap and assemble as a truncated cylinder, as assigned by your instructor.

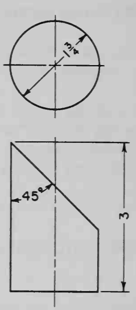


Fig. 11-12. Truncated cylinder.

LAYOUT FOR A CONE

In your metal work in the shop, you probably will be making a funnel or some other cone-shaped object of sheet metal. You can lay out any of these cone-shaped objects by following this procedure:

1. Draw two views of the object showing its size and shape, Fig. 11-13 (a).
2. Draw the stretchout with AC as the radius, Fig. 11-13 (b).
3. Transfer the equal spaces representing the circumference in the top view to the stretchout, Fig. 11-13 (c).
4. Use the distance CD to draw the arc which forms the lower edge of the funnel body. See Fig. 11-13 (d) below.

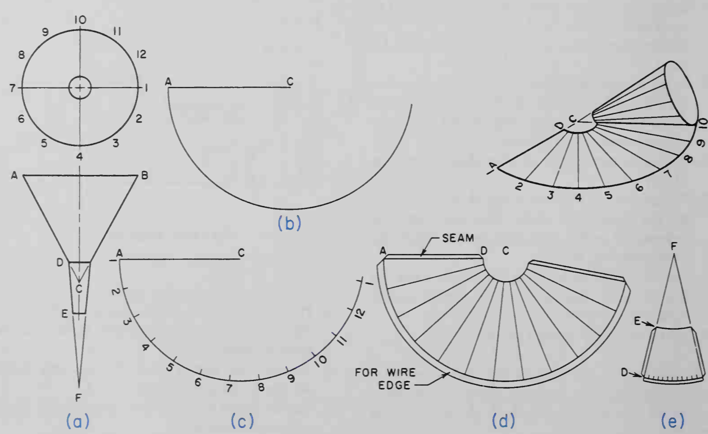


Fig. 11-13. Layout for a cone.

5. Add material for the seam on sides and for the wire edge.
6. Make stretchout for spout in similar manner, Fig. 11-13 (e).

DRAFTING ACTIVITY

1. Develop the pattern for the funnel or megaphone shown in Fig. 11-14.

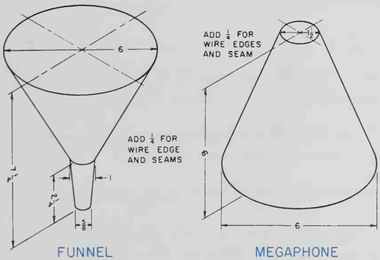


Fig. 11-14. Funnel and megaphone problems.

2. Letter your name on the pattern.
3. Cut out the pattern and assemble with cellophane tape. (Since this pattern may be used later in your metal work, allow for wire edges and seams.)

DRAFTING ACTIVITY

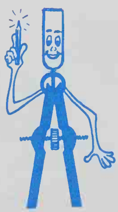
1. Select some commercial object commonly used around the house such as a cosmetic bottle, kitchen utensil or shop tool and design a suitable package for it.
2. Develop a layout for the package, lay out on a suitable package material and cut out, assemble and try it out.
3. Does it fit the design of the object? Is the package material suitable for protecting the object? What changes need to be made to improve the package design or conserve materials?

QUIZ – UNIT 11

1. Why are surface development drawings frequently referred to as "stretchouts?"
2. Name several types of workers who use surface development patterns.
3. Why are patterns laid out full-size?
4. In making a stretchout for a cylindrical object, how is the length of the stretchout measured? Is there another way in which this could be obtained?

NEW WORDS FOR YOU TO USE

1. Cylinder (sil'in-der)
2. Prism (priz'm)
3. Truncated (trung'kat-ed)



DRAFTY SAYS: "Always keep your pencil sharp. You can't do good work with a dull pencil."

Unit 12
ARCHITECTURAL DRAFTING

After studying this unit, you will know:
1. **What is architectural drafting.**
2. **How architectural styles differ.**
3. **What types of drawings are used in architectural work.**

The special field of drafting which deals with the preparation of drawings for commercial and public buildings as well as for houses, is known as architectural drafting. The planning of any structure requires three things: (1) design of the exterior and interior of the building; (2) preparation of drawings showing details of construction; and (3) written specifications (sometimes called "specs") which provide a description of such things as quality of materials to be used, kinds of finish to be applied to floors and walls, etc., kinds of hardware and types of electrical fixtures.

In many states, the above work is done by licensed architects. However, there is much the home owner can do in preliminary planning of a new house or in planning alterations for a current residence.

You may find that you will have a real interest in architectural drafting, so let's get started!

ARCHITECTURAL STYLE OF HOUSES

The architectural style of a house refers to its exterior appearance or design. Houses which have a particular architectural style can be divided into two broad classifications: the TRADITIONAL and the CONTEMPORARY. Fig. 12-1 shows two popular traditional styles and two contemporary styles.

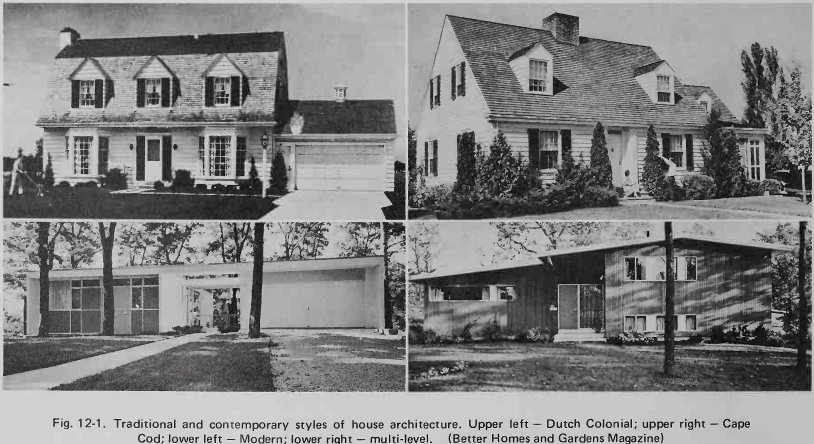


Fig. 12-1. Traditional and contemporary styles of house architecture. Upper left – Dutch Colonial; upper right – Cape Cod; lower left – Modern; lower right – multi-level. (Better Homes and Gardens Magazine)

TRADITIONAL HOUSES

The traditional styles had their beginning in certain historical periods of various countries. Each style has been influenced by the backgrounds of the people of the country in which the style originated, by the climatic conditions which had to be considered in building, and finally by the materials available. Some examples of traditional styles found in the United States are discussed here to help you in identifying some basic types.

The ELIZABETHAN, one of the many styles of English influence, is a one and one-half to a two-story structure with steep sloping gable roof, Fig. 12-2; frequently having dormer windows; large chimney; and an exterior of brick, stone, or stucco with half-timber construction.

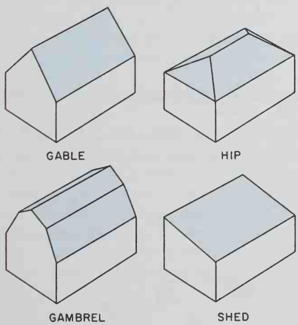


Fig. 12-2. Types of roofs.

The GEORGIAN style house is a two-story house characterized by well-balanced and well-proportioned masses in the exterior walls with many classic details, and chimneys, and a hip roof. The siding may be brick, stone, or wood.

SPANISH architecture features a one or a two-story house with a red-tile, low pitched roof; light colored stucco walls; and a patio (pa'ti-o), which lends itself to outdoor living. Spanish architecture is prevalent in the Southwest.

The DUTCH COLONIAL is a conservative compact house of one and one-half, two, or two and one-half stories. The second story frequently projects out over the first story, and the roof is of the gambrel type. The chimney is at the end. The exterior walls may be wood or stone, and they frequently are stone on the first story with wood above.

The CAPE COD is a one or one and one-half story house of traditional design, that is still popular today. It usually has a center chimney, steep gable roof with dormers (if a story and a half) and the exterior siding is usually wood such as clapboard or shingles. The windows of the Cape Cod house have small panes typical of colonial architecture and are flanked with shutters.

CONTEMPORARY HOUSES

The term "contemporary" in house architecture is limited to the ranch style house, the multi-level house, and the modern house. However, some traditional houses have been given a modern touch, and these houses are also classified as contemporary. The design of contemporary houses has been influenced by new building materials such as plywoods, plastics, and metals; they have been influenced also by today's casual, out-of-doors living.

There are certain characteristics which accompany most contemporary houses. These are: open-type, rambling floor plan with dining and living rooms combined; a utility room instead of a basement; the use of large glass areas — sometimes an entire wall will be glass, the lack of ornamentation on exterior walls, although these walls may consist of two or more materials such as wood, brick, or stone; and a low-pitched or flat roof.

The RANCH house is a one-story structure with a low-pitched hip or gable roof, a rambling floor plan and overhanging eaves. This is a very popular style of architecture today.

The MULTI-LEVEL house, frequently called a split-level house, consists of levels which are offset from each other by a few steps or as much as one-half story. The kitchen, dining room and living room are generally grouped on one level; the bedrooms, baths and storage closets on another level which is usually the highest level being over the garage or recreation room. It may or may not have a basement.

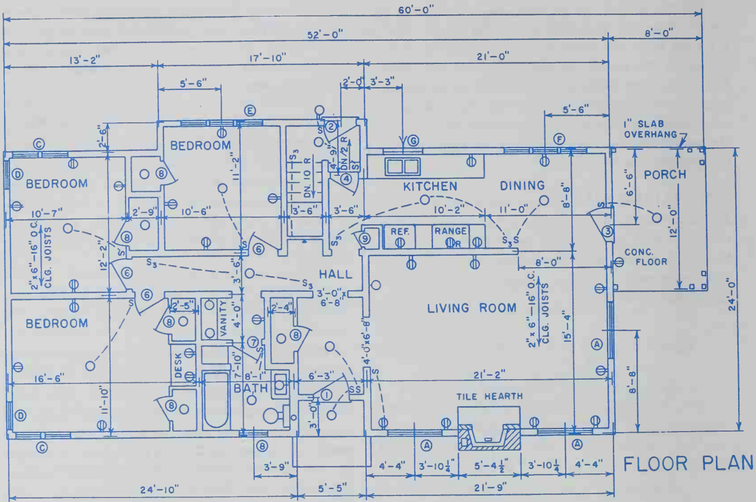


Fig. 12-3. Floor plan of a house.

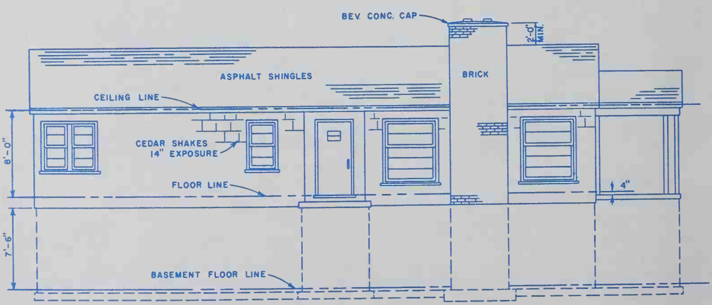


Fig. 12-4. A front elevation.

The MODERN house, may be a one-story, a two-story, or a multi-level dwelling, which features a flat or shed type (single pitch) roof, and large glass sections in exterior walls.

DESIRABLE ARCHITECTURAL FEATURES

Regardless of the style of house you choose, there are certain desirable features which you should consider when planning a house. These are:

(1) A protected or recessed entrance.
(2) An entrance hall that leads to the main areas of the house — living room, kitchen and bedrooms without using the living room as the traffic way.
(3) A kitchen which provides ample cabinet space with convenient distances.
(4) A family or recreation room with fireplace.
(5) Closet space for the entrance hall and each bedroom (two for the master bedroom).
(6) Storage space for seasonal household articles, tools and yard and garden equipment.

TYPES OF ARCHITECTURAL DRAWINGS

The architect makes use of several types of drawings in preparing the plans for the design and construction of a house. One of the first drawings to be made is the FLOOR PLAN (arrangement of rooms), Fig. 12-3. The floor plan contains most of the dimensions necessary in the construction of a house. It contains overall size; location of walls, windows, doors, stairs and electrical and plumbing details.

Once the owner is pleased with the floor plan and a style of architecture is decided upon, the architect starts to work on the ELEVATIONS, Fig. 12-4. Elevations are the exterior views of the walls — front, right-side, rear and left-side. These are sometimes referred to as the North Elevation, East Elevation, etc., meaning the direction which the elevation faces. The elevations show the windows, doors, trim and other details as they appear in the exterior.

In addition to the floor plan and elevations, DETAIL DRAWINGS of wall sections, fireplaces, etc., are made to show construction details, Fig. 12-5. These drawings are useful to the construction workers who build the house. The detail drawings also assure that construction will be done in a manner specified by the architect.

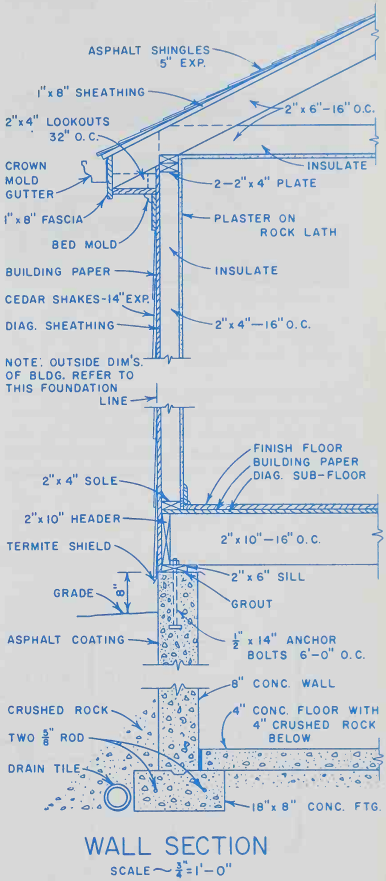


Fig. 12-5. Detail drawing of a wall section.

Another type of drawing is the PERSPECTIVE which is a pictorial view of the house to give the home owner a better understanding of how the house

Fig. 12-6. A perspective rendering.

Fig. 12-7. A scale model.

will look when completed. When perspective drawings have been given an artistic touch to include trees and shrubs, they are known as RENDERINGS, Fig. 12-6. To give the home owner an even more realistic view of the house, a scale model is sometimes prepared, Fig. 12-7.

ARRANGEMENT OF VIEWS

Unlike the views in orthographic projection, architectural views have more flexibility in their arrangement. All of the architectural views may be drawn on one sheet, but more likely several sheets will be required.

Let's see how well you can apply your knowledge of drafting to reading the architectural drawing in the next drafting activity.

DRAFTING ACTIVITY

Refer to Fig. 12-3 and answer the following questions:

1. What are the over-all dimensions of the house including the porch?
2. How much does the back bedroom extend beyond the corner bedroom?
3. Allowing 6 in. for wall thickness, what are the dimensions of the living room? Bedrooms?
4. What is the width of the kitchen?
5. What is the width of the bedroom hall?

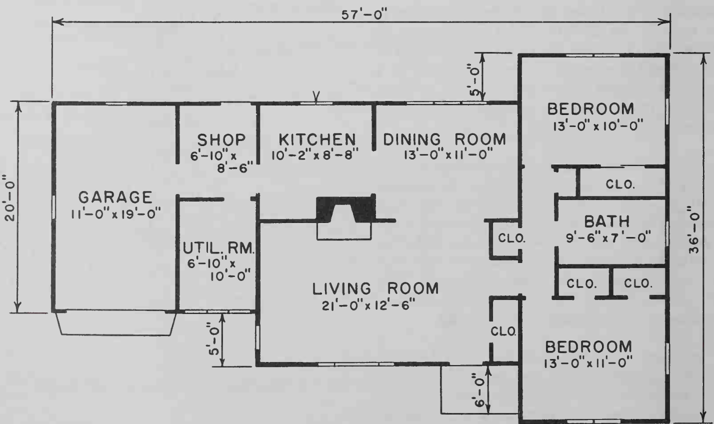
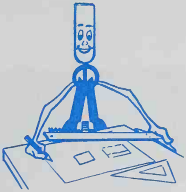


Fig. 12-8. Floor plan drafting problem.
Scale 1/4" = 1' – 0".



DRAFTY SAYS: "Do not slide instruments over drawing – lift to move."

Front hall? Stairwell?

6. How many duplex convenience outlets are required? Ceiling outlets? Wall outlets? Single-pole switches? Three-way switches?

DRAFTING ACTIVITY

1. Draw a floor plan of the house shown in Fig. 12-8. The interior dimensions shown are approximate room sizes and do not include wall thicknesses.
2. Include electrical, plumbing and kitchen equipment on your floor plan. Refer to Fig. 12-9 and 12-10 for details of these.
3. Dimension the drawing in the manner shown in Fig. 12-3.

DRAFTING ACTIVITY

1. Select one of the following, work out the design and draw a floor plan showing your ideas. Check with a materials supplier or building contractor to obtain help in estimating the cost of your recommended solution.
   a. Remodeling of a room at your house to provide for more storage for your hobby materials.
   b. Layout for a mountain cabin with 400 square feet of floor space maximum, to sleep four persons.
   c. Other architectural layout in which you have an interest.

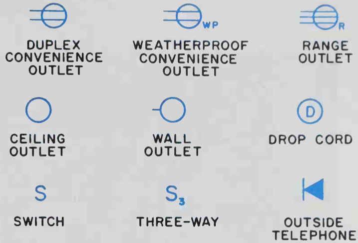


Fig. 12-9. Electrical symbols for floor plans.

QUIZ – UNIT 12

1. What three things are required in the planning of a house?
2. What are specifications?
3. What are the various roof types?

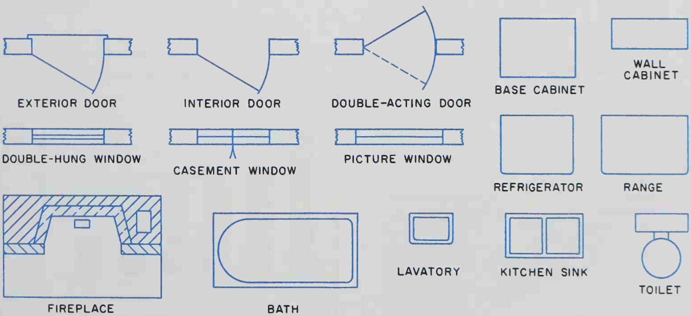


Fig. 12-10. Door, window, cabinet, plumbing and fireplace symbols.

Monticello, home of Thomas Jefferson, near Charlottesville, Va., designed and built by Jefferson, an architect, statesman and President of the United States. (Virginia Chamber of Commerce)

4. All house styles may be grouped into what two broad classifications? What styles can you name under each classification?
5. Name some desirable features which should be considered when planning a house?
6. What types of drawings are used in architectural drafting? What is the purpose of each?
7. What symbols are used for the following: (A) ceiling outlets, (B) wall outlets, (C) duplex convenience outlets and (D) switches?

NEW WORDS FOR YOU TO USE

1. Specification (spes-i-fi-ka'shun)
2. Traditional (tra-dish'un-al)
3. Contemporary (kon-tem'po-rer-i)
4. Pitch (pich)
5. Eaves (evz)
6. Renderings (ren'der-ings)
7. Gambrel (gam'brel)
8. Shakes (shaks)

Unit 13
GRAPHS AND CHARTS

After studying this unit, you will know:
1. What are graphs and charts.
2. How graphs and charts are constructed.
3. What advantages do graphs and charts offer.

Your drafting ability will be useful to you in many ways. One of these will be in making graphs and charts for work in other classes.

Graphs and charts refer to a type of drawing used by newspapers, magazines, schools and businesses to make factual information more understandable. You will want to learn how these are constructed so that you can use this type of drafting in your school classes.

You will have an opportunity in this unit to draw three types of graphs: bar, line and pie. An introduction to charts will also be made.

BAR GRAPHS

Bar graphs are used in making comparisons, such as school enrollments, Fig. 13-1. The items to be compared are represented by "bars" which extend on a scale of values.

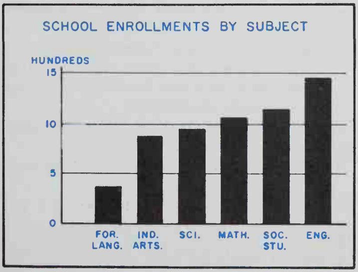


Fig. 13-1. A vertical bar graph.

There are several ways in which bar graphs may be drawn, Fig. 13-2. Bars may be drawn either in a vertical or a horizontal position. Color may also be used for variety and emphasis.

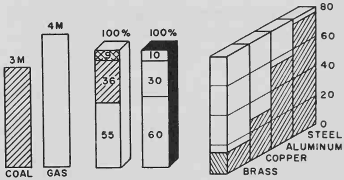


Fig. 13-2. Types of bars for graphs.

To draw a bar graph, follow these steps:

1. Use cross section paper or plain paper.
2. Decide on horizontal or vertical graph. If the number of items to be shown is large, it is advisable to use the horizontal, Fig. 13-3. Otherwise, use the vertical graph, Fig. 13-1.

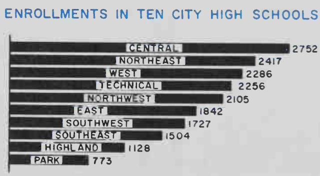


Fig. 13-3. A horizontal bar graph.

3. Figure size of rectangle into which the graph will fit. The number of bars, the space between, and the height, or scale, will need to be figured. The width of the bars and the space between them can be any reasonable width. Enough space should be provided to label each bar. The height or scale can be any reasonable distance. The height should extend to include the largest item in the graph. Show the scale in units, fives, tens, hundreds, etc., Fig. 13-1. Try to work out a rectangle of pleasing proportion.
4. Draw the bars, starting with the smallest and progress to the largest.
5. Label each bar and add necessary titles and codes.
6. Shade, fill, or color the bars.
7. Draw a border around graph if desired.

DRAFTING ACTIVITY

1. Use the following data (or data of your own), and draw a bar graph.
2. Data: Scores of high point players in basketball.

Year
____ – 749
____ – 529
____ – 648
____ – 218
____ – 484

LINE GRAPHS

To show the increase or decrease in something over a period of time, the line graph is often the most effective. The line graph in Fig. 13-4 (a), shows the number of basketball games won by a school over a period of 5 years. Fig. 13-4 (b) provides even more information by using 2 lines in the graph to show games won and games lost. When more than one line is used the lines differ in structure. Color may also be used to contrast the lines.

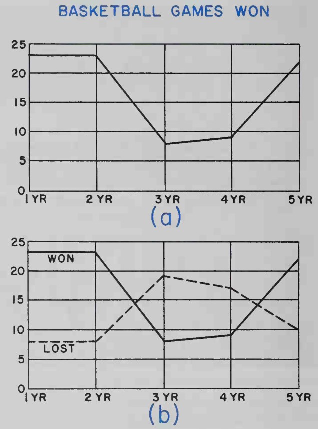
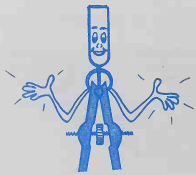


Fig. 13-4. Line graphs.

Two factors are shown in a line graph. One of these factors is held constant (does not change) for example, a period of time – a month or a year, and is laid off on the "x" (horizontal) axis. The other factor is variable (changes) for example, the number of games won or lost, and is laid off on the "y" (vertical) axis.

To construct a line graph, follow this procedure:

1. Figure size of rectangle needed to "frame" line graph. Find out how many divisions will be needed along the x and y axes and how much space should be provided each.
2. Make a freehand sketch of the graph showing layout of x and y axes.
3. Locate and draw rectangle for graph on cross sectioned or plain paper.
4. Lay out scale on x and y axes and draw grid (cross section) lines if plain paper is used.
5. Plot data.
6. Connect these points with a line.
7. Label the graph with title, necessary notes and codes.



DRAFTY SAYS: "Keep your hands clean."

DRAFTING ACTIVITY

1. Use the following data (or data of your own) and draw a line graph.
2. Data: Enrollment in Central High School for 5 years.

Year
____ – 416
____ – 428
____ – 509
____ – 637
____ – 814

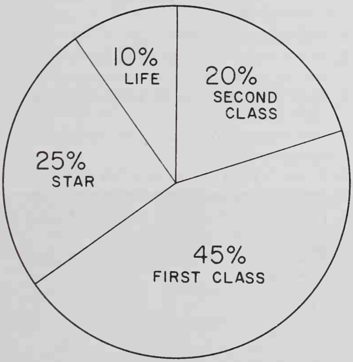


Fig. 13-5. A pie graph.

PIE OR CIRCLE GRAPHS

When the information you want to show represents 100%, or the whole, you will find the pie graph most useful. This type of graph is called a pie graph because the sections resemble pieces of pie. Such a graph enables a person to quickly observe how each part compares with the whole. The rank achieved in scouting by 60 youths attending a scout camp is shown in Fig. 13-5.

The sections of a pie graph may be left plain, cross hatched, or colored for contrast.

To construct a pie graph, follow this procedure:

1. Determine the size of the graph, based on space available and amount of information to be lettered within the sections.
2. Draw the circle.
3. Figure size of sections. The whole circle equals 100%; it also equals 360°. Therefore,
$$1\% = \frac{360}{100} = 3.6^{\circ}.$$
4. Start at any convenient place on the circle, usually at the top, and with the aid of a protractor, lay off each section.
5. Letter notes for each section, horizontally if possible, within the graph. When space is limited, letter outside the graph and extend a leader to the graph section.
6. Letter the title of the graph.

DRAFTING ACTIVITY

1. Use the following data (or data of your own) and draw a pie graph.

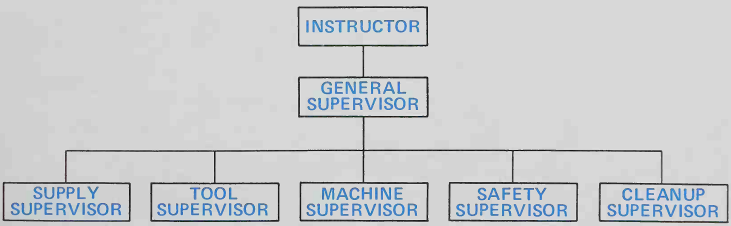


Fig. 13-6. An organizational chart showing a school shop personnel organization.

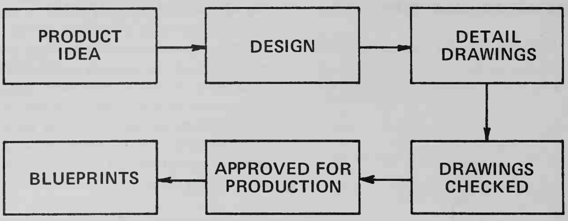


Fig. 13-7. Flow chart showing product development from idea to blueprint.

2. Data: Enrollment in high school by classes:

seniors	150	sophomores	300
juniors	225	freshmen	325

CHARTS

Charts, like graphs, are prepared to simplify the presentation of certain information, or to clarify a complicated process. Two types of charts which are commonly used are the ORGANIZATIONAL CHART, Fig. 13-6, and the FLOW CHART, Fig. 13-7. These charts may be drawn to any size appropriate for the information presented and the space available.

QUIZ – UNIT 13

1. What purpose do graphs serve?
2. What types of graphs are discussed in this unit?
3. Can you name and describe other graphs?
4. When would you use the horizontal bar graph rather than the vertical?
5. What determines the size of the rectangle "framing" a bar graph?
6. If you wanted to compare two items over a period of time which type graph would you use?
7. What is the best type of graph to use in illustrating how you spend a 24 hour day?
8. What is the purpose of an organizational chart? A flow chart?

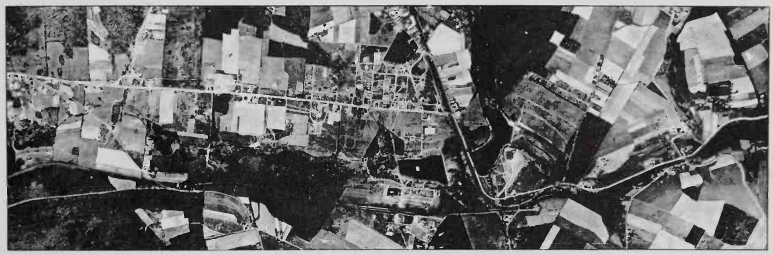
Unit 14
MAP DRAFTING

After studying this unit, you will know:
1. **How maps are drawn.**
2. **What are the kinds of maps.**
3. **What maps can tell you.**

Perhaps you have made a long trip by auto or by plane, hiked cross-country, or camped out. If you have, then you already know something about maps. This unit will help you understand the drafter's part in the making of maps.

Maps are one-view drawings known as topographical drawings, and are used to describe a portion of or all of the earth's surface. Topography means the shape of the land's surface including its hills, valleys, streams, lakes and trees. Frequently topographical maps show roads, cities, etc. Maps are drawn by topographical drafters who work from data gathered in the field by civil engineers and surveyors. The use of aerial photographs is reducing the amount of field work necessary, Fig. 14-1. A surveying crew

Fig. 14-1. Aerial photography is used in map making. (U. S. Geological Survey)



AERIAL PHOTOGRAPH USED IN THE PREPARATION OF MAP SHOWN BELOW

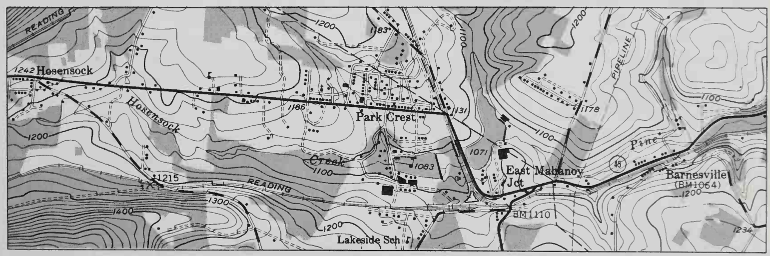


Fig. 14-2. Surveying crew at work.

gathering data for a new construction project is shown in Fig. 14-2. A map will be drawn before construction starts.

Travelers over America's highways depend upon road maps for direction to get to their destinations. Hikers and campers depend upon maps to guide them in strange territories. Architects and engineers need maps describing the shape of the land and the sub-soil to properly plan buildings and highways. A person building a house needs an accurate map of the boundaries of the lot in order to properly locate the house.

SCALE AND DIRECTION OF MAPS

Maps, like many other objects, are drawn to scale. This scale may range from 1 in. equaling a few feet to 1 in. equaling several hundred miles. North on a map is assumed to be at the top of the map unless otherwise indicated by an arrow. Following are descriptions of maps which are used by all of us.

GEOGRAPHIC MAPS

This map is the type found in your geography books and shows the earth's physical features – both natural and those that are "made." The geographic map usually represents large areas and only the principal mountains, streams, lakes, cities, roads, etc. are shown. Smaller areas may be shown also on a geographic map and on such maps all or nearly all of the physical features of an area may be shown.

CONTOUR MAPS

A map which shows the variation in elevations of the land by lines connecting points of the same elevation is called a contour map, Fig. 14-3. Imagi-

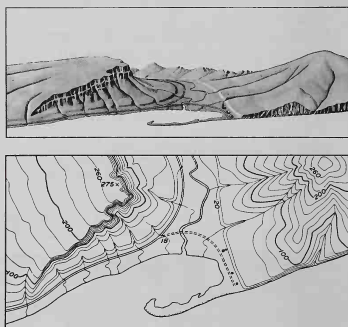


Fig. 14-3. A contour map. (U. S. Geological Survey)

nary lines on the earth's surface (as if the earth had been sliced horizontally at uniform heights) are drawn on the map to represent the slope or shape of the land, Fig. 14-4. The vertical difference between contours may range from less than a foot on small maps to over 200 ft. on larger maps. When the contours are close together, the surface is steep; when they are far apart, the slope is less steep. The contours are numbered to indicate elevation in feet from some fixed elevation such as sea level.

Contour maps are necessary in the initial planning of buildings, highways, airfields and other construction projects.

PLAT MAPS

A plat (or plot) is the map of a small piece of ground such as a building site for a house, school or

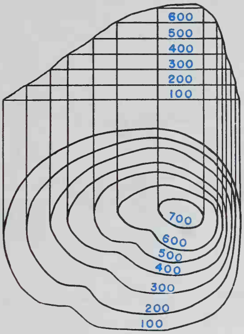


Fig. 14-4. Drawing contour lines.

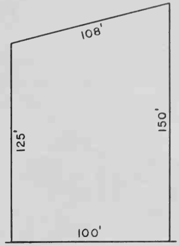


Fig. 14-5. A plat map.

camp, Fig. 14-5. If your parents own their own house, they may have a plat of their lot showing the boundary lines of the property and the location of the house upon the lot.

ROAD MAPS

State highway maps are available for every state in the union showing interstate, state and county roads. In addition, the map shows types of road surfaces, cities, towns, distances between points, a scale of miles, state parks and other points of interest. Data for these maps are gathered by state highway survey-

Fig14-6. Drafter at work on a highway map.
(Arizona Highway Dept.)

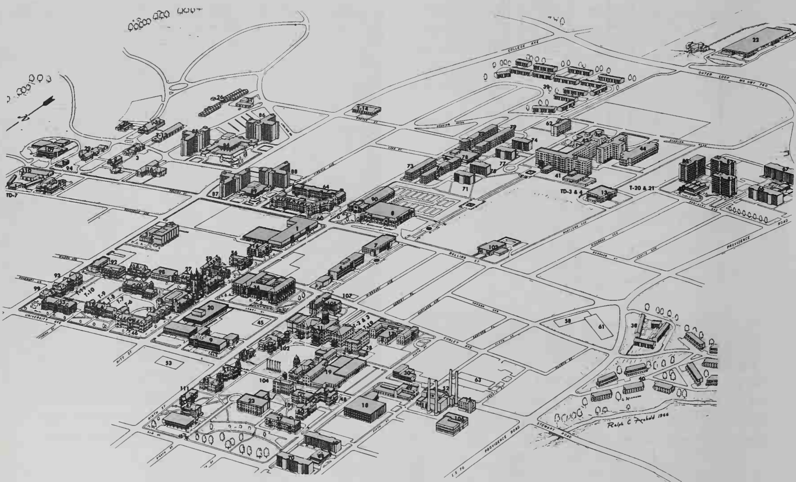


Fig. 14-7. A pictorial map is easy to read and follow.
(University of Missouri)

ing crews and are continually being revised and brought up-to-date by map drafters, Fig. 14-6.

Street maps for the principal cities of the state are usually shown around the edge of the state map. Highways, through and around the cities, are shown as well as the main streets of the city.

PICTORIAL MAPS

Pictorial maps are issued by cities, governmental agencies, civic organizations and tourist agencies to provide an over-view of an area showing principal points of interest, Fig. 14-7. You will observe the pictorial drawing has been used in the making of these maps. The chief purpose of these maps is to provide a "birds-eye-view" of an area, so that a stranger may readily see the location of certain buildings and points of interest. While these maps may not be as accurate in detail as some of the maps discussed previously, they are an effective means of giving directions.

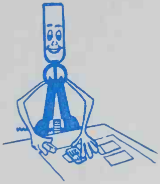
MAP READING ACTIVITY

1. From a highway map of your state, plan a trip to another city within your state and to a third city and return.
2. Figure the mileage for this trip.
3. Write out the directions for someone else to follow this same route.

DRAFTING ACTIVITY

Draw one of the following maps showing prominent places and streets or roads. Use an appropriate scale. The map should be neatly drawn, and should be easily understood by another person expecting to follow it.

1. Your route from home to school.
2. Your paper route.
3. The plot plan of your house and lot. Locate your house on the plot and dimension.



DRAFTY SAYS:

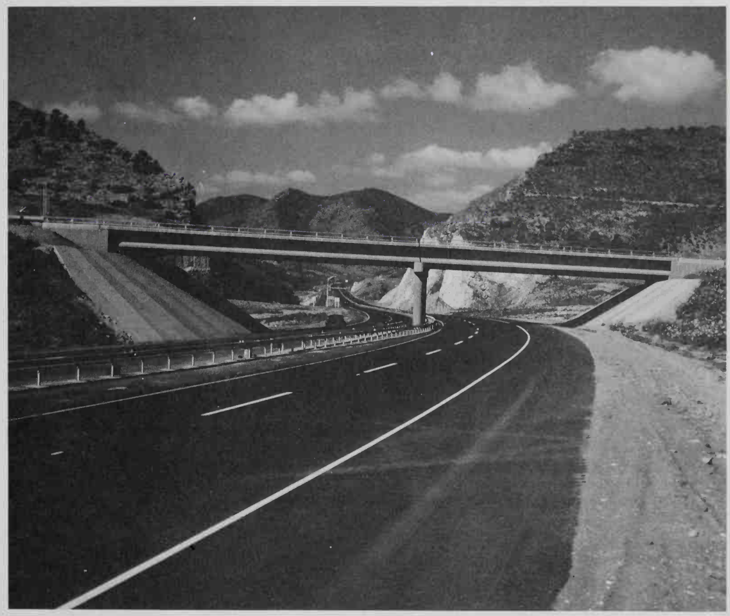
"When erasing, use a shield to protect nearby lines."

QUIZ – UNIT 14

1. Maps are the result of the work of several individuals. Who are these persons and what part does each perform in map making?
2. What features are shown on topographical maps?
3. What is a geographic map and how is it used?
4. Contour maps are used for what purpose? How do they differ from other maps?
5. What is the plat map and when is it used?
6. How do pictorial maps differ from other types of maps? What is the principal use of these maps?

NEW WORDS FOR YOU TO USE

1. Contour (kon'toor)
2. Surveying (ser-va'ing)
3. Topographical (top-o-graf'i-kal)



Road maps direct us to many interesting places. Shown above is a scene in the Colorado mountains. (Colorado Department of Highways)

Fig. 15-1. Positive print making machine in use. (AM-Bruning Div.)

Unit 15
MAKING AND READING BLUEPRINTS

After studying this unit, you will know:
1. **What kinds of prints are used today.**
2. **How these prints are made.**
3. **What skills are needed in reading drawings and prints.**

Drawings and blueprints are the chief means of conveying an idea for a new product to the workers who produce it. For example, engineers who want to communicate an idea for an improved rocket device must make use of drafting to communicate that idea to detail drafters and to the workers who will build the device. This is why drafting is known as the "language of industry."

Often, several copies of the drawing are needed for the various workers on a job. It would be too expensive to supply everyone with an original drawing, so duplicates in the form of prints are made.

Such prints are often referred to as "blueprints," because the original type of print was blue with white lines. However, in addition to blueprints, there are

other types of prints called "positive prints" which have dark lines on a light background. They are in common use today in schools and industry.

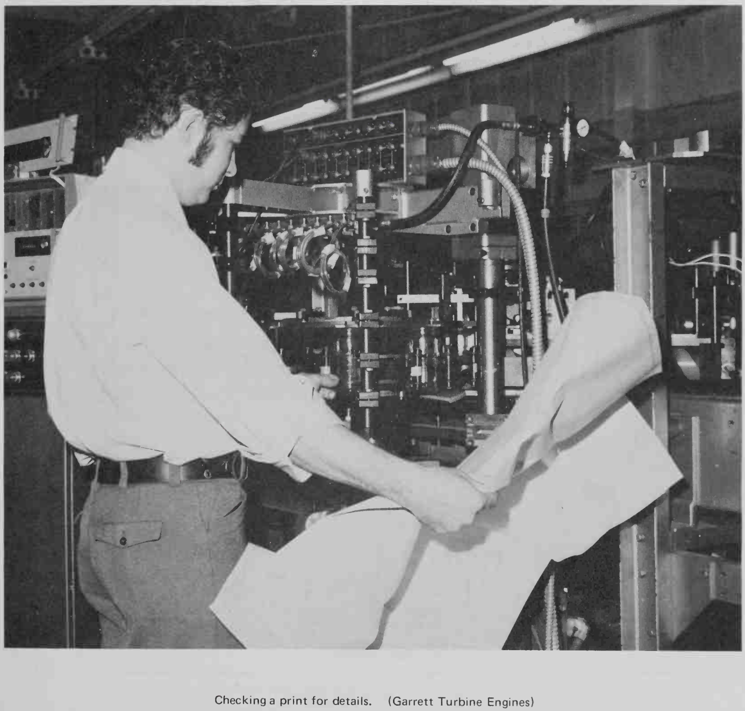
In this unit, you will learn how prints are made, and you will also get some experience in reading prints.

HOW PRINTS ARE MADE

Before prints can be produced, drawings must be made on thin translucent paper or cloth. Experienced drafters usually make the original drawing on vellum (translucent paper) from which the prints are made. This saves the time of "tracing" the drawing later. (Past practice was to trace the original drawing on transparent paper and make prints from the tracing.)

In making the prints, the original drawing on vellum serves the same purpose as a negative in photography. The drawing is placed over a chemically coated, light-sensitized paper. Then, it is exposed to a strong, artificial light contained in a print making machine, Fig. 15-1. During the printing process, the lines and the lettering on the drawing protect the chemical sensitizers on the paper and an exact copy (print) of the original drawing is produced.

Many industries choose to photograph the original drawing on microfilm to conserve storage space.



Checking a print for details. (Garrett Turbine Engines)

When additional prints are needed, the microfilm can quickly be retrieved and prints made. The development of prints will be discussed under the types of prints which follow.

BLUEPRINTS

The blueprint is a print having white lines on a blue background. Perhaps you have seen one of these. It is the least expensive print to make; it is quite durable under continuous use; and it does not fade readily when exposed to a strong light, such as the sun. Because of the blue background, however, it is difficult to make changes or notes on the print.

Exposing the blueprint paper to light may require as little as 30 seconds to as much as 3 minutes or more depending on the brand of paper and the intensity of the light. After the blueprint paper has been exposed to the light, the chemical on the coated paper receiving the light becomes insoluble and when washed in water turns blue. The chemical beneath the lines on the tracing has not been exposed to light, and therefore dissolves in the washing process, leaving the white paper showing as white lines.

DIAZO PROCESS

A more recent and widely used process of making prints is the diazo process which produces positive type prints with dark lines on a white background. These prints may have blue, black, brown, red or other colored lines and are often referred to as whiteprints, directline prints, black line, brown line, etc. This process uses the light sensitivity of certain diazo compounds and is available in dry, moist or pressurized form.

The original translucent drawing and sensitive diazo paper are inserted into a diazo type print machine and exposed to the light source which destroys the unprotected diazo compound. The orig-

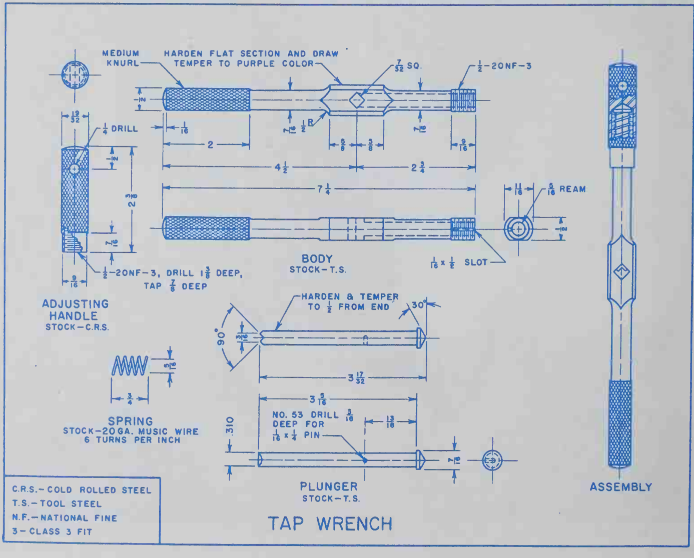


Fig. 15-2. Print of a tap wrench.

inal drawing is returned to the operator and the exposed sensitive paper is carried through to the developing section of the machine. Here, it is exposed to a chemical which develops the print.

ELECTROSTATIC PROCESS

The electrostatic process is a means of producing paper prints and intermediate transparencies from original drawings or microfilm. This process, commonly referred to as Xerography, will develop a positive print on unsensitized paper.

The convenience and simplicity of the electrostatic process has resulted in its increased use in reproducing prints and other documents. Intermediate transparencies may also be produced by this process.

BLUEPRINT READING

Blueprint reading is a matter of understanding the types of drawings, lines, symbols and notes. You have been studying these in previous units and should be able to read most of the prints in your school shop. The prints for two advanced projects, one metal and one wood, which you may have an opportunity to make, are shown in Figs. 15-2 and 15-3. Let's see how much information you are able to obtain concerning the size, location of parts, shape, quantity and kinds of materials used.

BLUEPRINT READING ACTIVITY

Study the print in Fig. 15-2 and answer the following questions in full detail:

1. How many separate parts are there to the tap wrench?
2. What is the diameter of the knurled part of the adjusting handle?
3. To what depth is the adjusting handle threaded? What is the size and type of thread?
4. What kind and size of stock is needed to

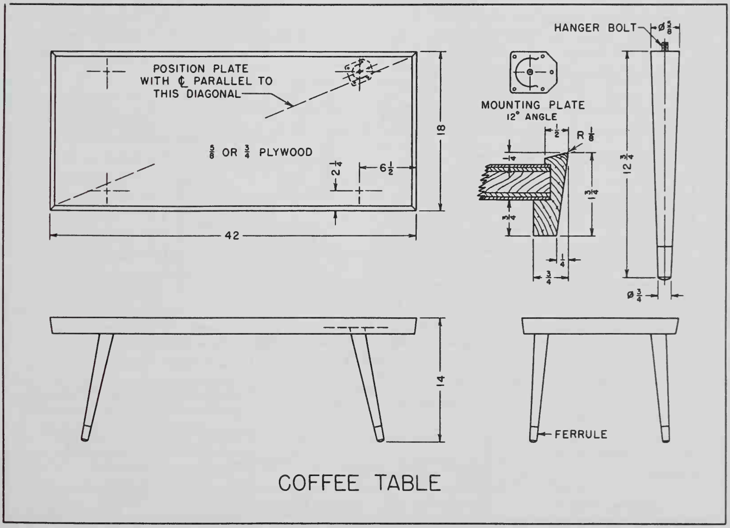


Fig. 15-3. One type of positive print showing a coffee table.

make the tap wrench body?

5. What is the thickness of the flat section of the body?
6. What is the size of the hole in the body which contains the plunger?
7. What is the diameter of the plunger stem? The plunger cap?
8. Describe the means by which the plunger is kept aligned in the body.
9. The spring is made from what material? What is its inside diameter?
10. What parts of the tap wrench are hardened and tempered?
11. Check with your instructor on the price of materials and figure the cost of this project.

BLUEPRINT READING ACTIVITY

Study the print in Fig. 15-3 and answer the following questions concerning the table:

1. What are the over-all width, length and height dimensions of the coffee table?
2. What are the dimensions of the legs?
3. How are the legs fastened to the top?
4. Where are the mounting plates positioned?
5. Of what material is the top constructed?
6. What are the over-all dimensions of the side rail?
7. Other than wood screws, how many metal parts are used in constructing this table? What are they?
8. Check with your instructor on the price of materials and figure the cost of this project.

Following are two blueprints from industry. Let's see how well you are able to read actual blueprints used in industry.

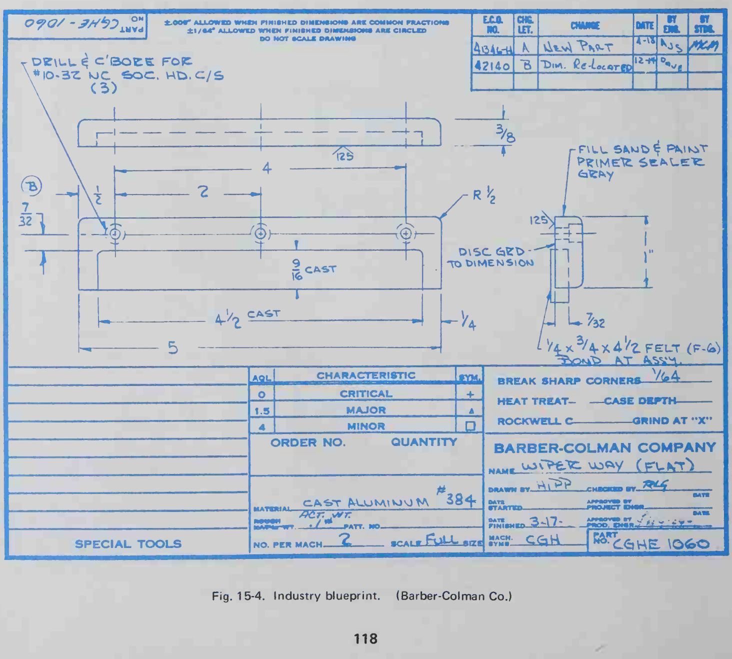


Fig. 15-4. Industry blueprint. (Barber-Colman Co.)

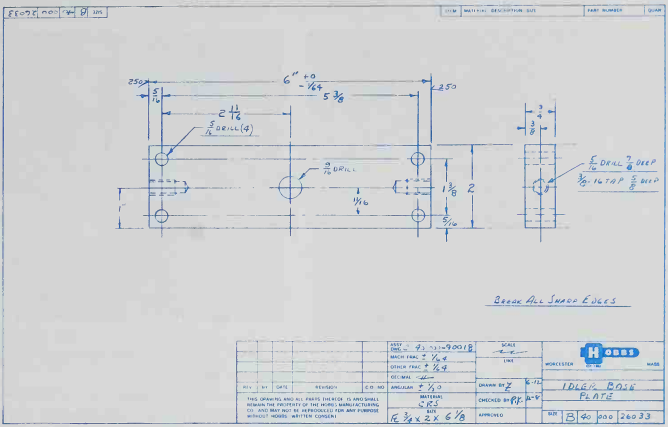


Fig. 15-5. Industry blueprint. (Hobbs)

BLUEPRINT READING ACTIVITY

Study the print in Fig. 15-4 and answer the following questions:

1. What is the name of the part?
2. What is the part number?
3. How many separate parts are there?
4. What is the overall size of the cast aluminum part?
5. For what size cap screw is this part drilled and counterbored?
6. What is the dimension of the recess in the aluminum casting for the felt wiper?
7. What is the distance between holes?
8. How is the casting to be finished?
9. What is the size of the felt wiper?
10. How and when is the felt wiper to be installed?

BLUEPRINT READING ACTIVITY

Study the print in Fig. 15-5 and answer the following questions:

1. What is the name of the part?
2. What is the part number?
3. What is the overall size of the part?
4. How many holes are to be drilled?
5. How many holes are to be threaded?
6. What is the size of the pilot drill for these threaded holes?
7. How deep are they drilled?
8. What are the two dimensions separating the four holes that are alike?
9. What is the dimension of the center hole?
10. How are the sharp edges to be treated?

QUIZ – UNIT 15

1. What kinds of prints are discussed in this unit? How do they differ?
2. Before prints can be made, what must be prepared? How are these prepared?
3. In what ways may prints be exposed?
4. Explain how prints are developed.
5. What are the advantages and disadvantages of blueprints? Diazo prints?

NEW WORDS FOR YOU TO USE

1. Ammonia (a-mo'ni-a)
2. Dichromate (di-kro'mat)
3. Durable (dyoor'a—bel)
4. Insoluble (in-sol'u-ble)
5. Knurl (nurl)
6. Potassium (po-tas'i-um)
7. Solution (so-loo'shun)
8. Translucent (trans-loo-sent)

Unit 16
COMPUTER GRAPHICS

After studying this unit, you will know:
1. **What is computer graphics.**
2. **How does computer graphics assist the drafter.**
3. **How will the computer affect the work of the drafter in the future.**

Computers are everywhere today! They are in video game parlors, homes, schools and businesses, Fig. 16-1. They are also very common in design and drafting rooms of industry.

WHAT IS COMPUTER GRAPHICS?

Computer graphics is the presentation of various geometric and chart forms with the aid of a computer, Fig. 16-2. You have observed computer graphics while watching TV programs. Images of space vehicles, weather patterns across the nation, and simulated video game characters are created using computer graphics.

Computer Aided Design and Drafting (CADD) is the development of designs and drawings of mechanical parts. They also include architectural structures and area maps. The computer is simply a mathematical

Fig. 16-1. Computers are a part of everyday life. In this application, a student is introduced to a personal computer by playing a game. (IBM)

Fig. 16-2. A designer at a computer terminal working with a design of a space vehicle. (3M Company)

machine. It aids a person in calculating and obtaining solutions to problems. This saves large amounts of time.

NEEDS AND TRENDS

In today's high-tech world, it is necessary to design equipment in a very short time. This is much faster than it was just a few short years ago. Today, there are more materials and processes available to designers. There are also greater demands placed upon the products we use. Designers and drafters in industry will be making even greater use of computers in the future, Fig. 16-3.

Fig. 16-3. Design-drafter making use of a computer in designing an electrical circuit. (Bell Labs)

Fig. 16-4. Computer input devices — keyboard, digitizer tablet and cathode ray tube. (McDonnell-Douglas, St. Louis)

EQUIPMENT IN COMPUTER GRAPHICS

The computer graphics system in industry includes many devices. These devices permit the designer-drafter to have a two-way "conversation" with the computer. That is, there are devices to input information to the computer — usually a keyboard or digitizer tablet and a cathode ray tube (CRT), Fig. 16-4. These are called "terminals." This information is "input" to the computer and processed.

The designer-drafter then receives "output" from the computer. The CRT, Fig. 16-4, gives immediate feedback to the operator. This information may also be modified (changed) or stored for future use. Output may also be received by means of a plotter, Fig. 16-5. These plotters take the information processed

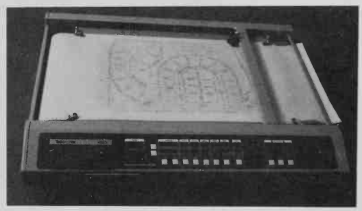


Fig. 16-5. Plotters produce hard (paper) copy of graphic materials. (Tektronix, Inc.)

by the computer and produce hard (paper) copy in the form of drawings, charts or tables. There are other output devices for special needs. One example is the artwork generator. This device produces extremely accurate drawings for manufacturing electronic printed circuit boards, Fig. 16-6.

Design drafting rooms in industry are making greater use of stand-alone computer systems. These are capable of performing computer-aided design and drafting functions and also producing hard copy.

DESIGNER-DRAFTER AND COMPUTER WORK TOGETHER

The computer is not a magic device that creates drawings on its own. The computer has no intelligence. It is simply an extremely fast machine for processing data supplied by an intelligent person. The computer is another tool for the designer-drafter to use in performing creative functions.

COMPUTER GRAPHICS AND THE FUTURE

The designer-drafter of the future will be using all types of computer assisted devices. He or she will still need to understand the basic principles of drafting.

Modern technology does not allow long periods of time in developing new products and processes. This is where computer graphics assists the designer-drafter to speed up mathematical functions and repetitive drawings. Computer graphics gives the designer-drafter more time for creative and productive thinking.

QUIZ—UNIT 16

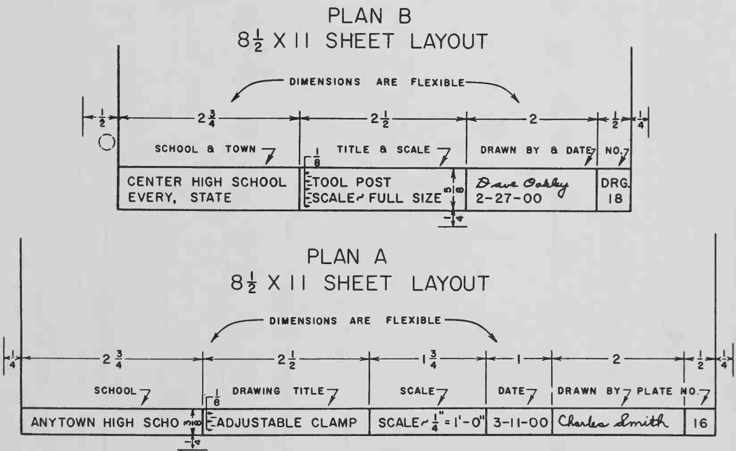
1. Describe, in your own words, the meaning of the term computer graphics.
2. How does the computer aid the designer-drafter?
3. What effect will the computer have on the designer-drafter and his or her work?

Fig. 16-6. Artwork generators produce precision pattern layouts for electronic circuitry. (Gerber Scientific Instrument Company)

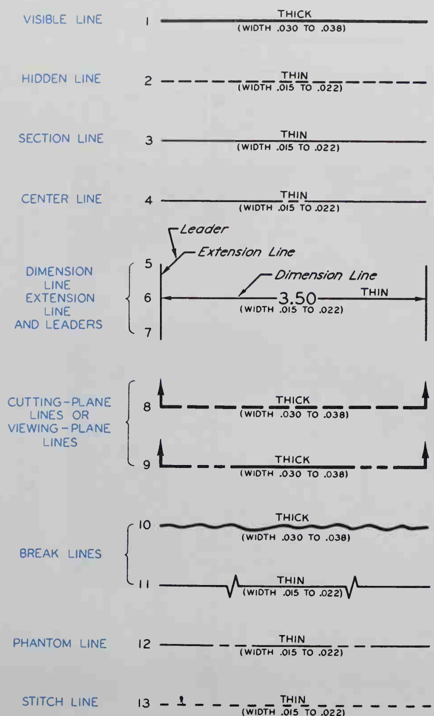
4. With the use of the computer, will the drafter-designer need to understand basic drafting? Why?

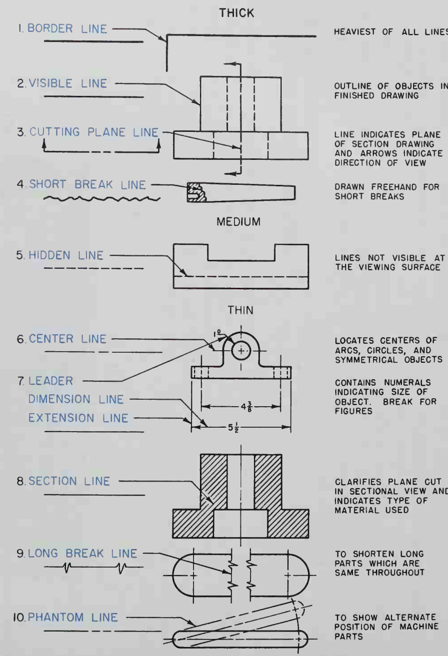
NEW WORDS FOR YOU TO USE

1. Computer Graphics (com-pu'-ter graf'-iks)
2. Digitizer (dige'-i-tizer)
3. Terminals (term'-i-nuls)
4. Input (in'-put)
5. Output (out'-put)
6. Plotter (plot'-ter)
7. Generator (gen'-er-a-tor)



Suggested border and title block layouts for vertical and horizontal drafting plates.





Left. Alphabet of lines using two line weights.
Above. Application of alphabet of lines in drawings.

METRIC — INCH EQUIVALENTS

INCHES		MILLI-METRES	INCHES		MILLI-METRES
FRACTIONS	DECIMALS		FRACTIONS	DECIMALS	
	.00394	.1	15/32	.46875	11.9063
	.00787	.2		.47244	12.00
	.01181	.3	31/64	.484375	12.3031
1/64	.015625	.3969	1/2	.5000	12.70
	.01575	.4		.51181	13.00
	.01969	.5	33/64	.515625	13.0969
	.02362	.6	17/32	.53125	13.4938
	.02756	.7	35/64	.546875	13.8907
1/32	.03125	.7938		.55118	14.00
	.0315	.8	9/16	.5625	14.2875
	.03543	.9	37/64	.578125	14.6844
	.03937	1.00		.59055	15.00
3/64	.046875	1.1906	19/32	.59375	15.0813
1/16	.0625	1.5875	39/64	.609375	15.4782
5/64	.078125	1.9844	5/8	.625	15.875
	.07874	2.00		.62992	16.00
3/32	.09375	2.3813	41/64	.640625	16.2719
7/64	.109375	2.7781	21/32	.65625	16.6688
	.11811	3.00		.66929	17.00
1/8	.125	3.175	43/64	.671875	17.0657
9/64	.140625	3.5719	11/16	.6875	17.4625
5/32	.15625	3.9688	45/64	.703125	17.8594
	.15748	4.00		.70866	18.00
11/64	.171875	4.3656	23/32	.71875	18.2563
3/16	.1875	4.7625	47/64	.734375	18.6532
	.19685	5.00		.74803	19.00
13/64	.203125	5.1594	3/4	.7500	19.05
7/32	.21875	5.5563	49/64	.765625	19.4469
15/64	.234375	5.9531	25/32	.78125	19.8438
	.23622	6.00		.7874	20.00
1/4	.2500	6.35	51/64	.796875	20.2407
17/64	.265625	6.7469	13/16	.8125	20.6375
	.27559	7.00		.82677	21.00
9/32	.28125	7.1438	53/64	.828125	21.0344
19/64	.296875	7.5406	27/32	.84375	21.4313
5/16	.3125	7.9375	55/64	.859375	21.8282
	.31496	8.00		.86614	22.00
21/64	.328125	8.3344	7/8	.875	22.225
11/32	.34375	8.7313	57/64	.890625	22.6219
	.35433	9.00		.90551	23.00
23/64	.359375	9.1281	29/32	.90625	23.0188
3/8	.375	9.525	59/64	.921875	23.4157
25/64	.390625	9.9219	15/16	.9375	23.8125
	.3937	10.00		.94488	24.00
13/32	.40625	10.3188	61/64	.953125	24.2094
27/64	.421875	10.7156	31/32	.96875	24.6063
	.43307	11.00		.98425	25.00
7/16	.4375	11.1125	63/64	.984375	25.0032
29/64	.453125	11.5094	1	1.0000	25.4001

INDEX

Goodheart-Willcox's BUILD-A-COURSE Series

woodworking

by

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Modern General Shop

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INTRODUCTION

This Build-A-Course text in WOODWORKING is a first or exploratory course. It provides instruction and information concerning tools, machines and materials that are basic to the broad area of woodwork.

Hand tool operations are stressed since the beginning students will be using them for most of their work. Only the most basic power machine operations that are practical in a beginning course have been included. An important unit on wood finishing provides instruction on the application of modern finishing materials that are adaptable to the school shop.

The importance of careful planning and good design is emphasized. A number of shop tested projects are presented. They range from "starter" projects, where complete plans are provided, to elective projects where only a photograph and overall size suggestions are given.

A number of jigs and special setups are shown that will help the inexperienced students perform difficult operations with speed and accuracy. They will also give students some appreciation of procedures used in production woodwork.

The importance of safe work habits and practices in using both hand tools and power machines is stressed by listing of safety rules, as well as concise directions in operational procedures.

TO THE STUDENT

Wood is one of our greatest natural resources and is used to construct our homes, furniture and many articles that we use every day. More than a million people are employed in trades and industries directly related to wood and wood products.

Woodworking has always been of great interest to young people, for learning about wood and how to use tools and machines is a fascinating experience. Added to this is the personal satisfaction that comes from the actual construction of attractive and useful projects with equipment that is similar to that used in industry.

In this course you will learn to thoughtfully plan your work, as well as develop important skills in using tools and machines. Furthermore, you will develop an appreciation for good workmanship. You will experience pride in building things for yourself and others. Very likely, you will want to develop a shop area at home where you can continue to enjoy woodworking as a hobby. You may also want to consider the many important and interesting careers offered by the wood and wood products industry.

Willis Wagner

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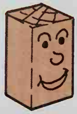
GENERAL SAFETY RULES



WOODY Says:

"An important part of your experience in woodworking will be learning to follow safe practices and procedures that will prevent injuries to yourself and others. Give close attention to the instructions and demonstrations given by your instructor and study the directions for using tools listed in this book. As you learn to use a tool the correct way, you are also learning to use it the safest way.

Study and learn the safety rules listed below. Your instructor may recommend some additional ones that apply to a specific shop. It is desirable for you to be highly interested in your work but you must guard against becoming so "wrapped-up" in it that you forget to work safely.

SECURE APPROVAL: Secure the instructor's approval for all work you plan to do in the shop. He or she is the one to decide if the work can and should be done and will be able to suggest the best, easiest and safest way to do it.

CLOTHING: Dress properly for your work. Remove coats, sweaters, and jackets; tuck in your tie and roll up your sleeves. It is advisable to wear a shop apron.

EYE PROTECTION: Wear safety goggles or a face shield when doing any operation that may endanger your eyes. Be sure you have enough good light to see what you are doing without straining your eyes.

CLEAN HANDS: Keep your hands clean and free of oil or grease. You will do better and safer work, and the tools and your project work will stay in good condition.

CONSIDERATION OF OTHERS: Be thoughtful and helpful toward other students in the class. Caution them if they are violating a safety rule.

TOOL SELECTION: Select the proper size and type of tool for your work. Use only tools that are sharp and in good condition. Inform your instructor if tools are broken, have loose handles, or need adjustments.

CARRYING TOOLS: Keep edged and pointed tools turned down and do not swing your arms or raise them over your head while carrying them. Do not carry sharp tools in your pockets.

CLAMPING STOCK: Wherever possible, mount your work in a vise or clamp it to a bench. This is especially important when using chisels, gouges or carving tools.

USING TOOLS: Hold a tool in the correct position while using it. Most edged tools should be held in both hands with the cutting motion away from yourself and other students. Be careful when using your hand or fingers as a guide to start a cut. Test the sharpness of a tool with a strip of paper or a scrap of wood. Do not use your fingers.

BENCH ORGANIZATION: Keep your project material carefully organized on your bench with tools located near the center. Do not "pile" tools on top of each other. Never allow edged or pointed tools to extend out over the edge of the bench. Close your vise when it is not in use and see that the handle is turned down. Keep drawers and cabinet doors closed.

FLOOR SAFETY: The floor should be clear of scrap blocks and excessive litter. Keep projects, sawhorses and other equipment and materials you are using out of traffic lanes. Wipe up immediately any liquids spilled on the floor.

MATERIAL AND PROJECT STORAGE: Store and stack your project work carefully. Straighten the lumber rack when you remove a board. Do not leave narrow strips protruding from the end of the rack, especially at or near eye level.

LIFTING: Protect your back muscles when lifting heavy objects. Have someone help you and lift with your arm and leg muscles. Secure help with long boards, even though they are not heavy.

FIRE PROTECTION: Apply and handle finishing materials only in approved areas. Close cans of finishing materials and thinners immediately after use. Use flammable liquids in very small quantities. Be sure the container is labeled. Dispose of oily rags and other combustible materials immediately or store them in an approved container. Secure the instructor's approval before you bring any flammable liquids into the shop.

INJURIES: Report all injuries, even though slight, to your instructor."

Unit 1
PLANNING YOUR WORK

After studying this unit, you will know:
1. **Why it is important to plan your work.**
2. **What things you should consider when selecting a woodworking project.**
3. **How to make pictorial sketches of project ideas.**
4. **How to make a plan of procedure and bill of material.**

Planning is thinking through an activity, or undertaking, before starting it. It may be as simple as developing a schedule for the day, or as complicated as planning a new school building or a new jet airliner. The engineering departments of industrial organizations deal with such planning activities as: product selection and design, equipment selection and plant layout, production sequence and timing, and estimating costs of a new product. They realize that careful planning will save time, energy, materials, and will insure a good product, Fig. 1-1.

Planning is a very important part of your work in the school shop. Mass production projects, Fig. 1-2, usually include all of the activities employed by industry. Careful planning will help you avoid mistakes and get more work done. And you will seldom need to ask your instructor "What do I do next?"

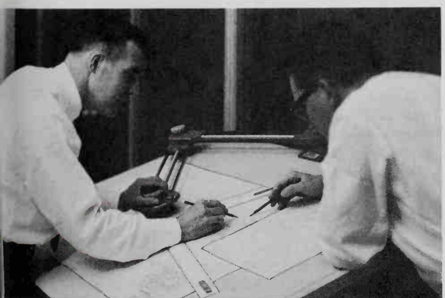


Fig. 1-1 Drawing is the language of design. Here designers discuss design problem. (Charles Bruning Co.)

A complete planning operation in woodwork includes the following steps: selecting a project, making a pictorial sketch, developing or refining the design, making a working drawing, preparing a step-by-step procedure, listing tools and machines that will be used for the work and preparing a bill (list) of material. See Figs. 1-1 and 1-2.

SELECTING PROJECTS

If this is your first course in the shop, your instructor will probably assign your first project and provide you with the plans you need.

For your second or third project, you may have an opportunity to select from a group of projects. You probably will be expected to develop some of the planning materials. As you gain experience and develop ability in your shop work, you will want to select and plan your own projects (with the help of your instructor).

When you select a project you must consider the following: how much time it will take, your ability, are the tools and materials available, how much will it cost, is there space to store it during construction, is it something you need or will enjoy building. If it is an article for your home you should secure your parents' ideas on style, color, finish or size.

Beginning students may tend to overestimate their ability and may undertake projects that are too difficult. It is not satisfying to "wind-up" at the end of the term with half-finished projects.

There are many sources for woodworking projects and ideas. Your shop or school library should be

Fig. 1-2. Careful planning insures success of mass production projects. View shows main assembly station for a peg-game board. Assembly jigs are mounted on a panel that is revolved counterclockwise.

checked. Stores and gift shops show many articles made of wood. Homecraft and household magazines offer ideas for shop projects.

PROJECT DESIGN

The things you make in the shop should be well designed. They should serve the purpose for which they were intended and be attractive in appearance. The finest workmanship and finish will not "make-up" for poor design.

Learning to recognize good design will take time and effort. You should know some of the simple rules concerning balance, proportion and unity. One of the best ways to improve your ability along this line is to study objects that are well designed.

Today, designers place great emphasis on function (usefulness). They also look for: smooth, trim lines; simple shapes and forms; and interesting grain patterns, colors and textures. They are cautious about using extra shapes, carvings and inlays just to add to the appearance.

Check the design you have selected or developed to see if it is the correct size. A book rack should be the right size for the books it will hold. The height of a coffee table or foot stool must be correct for its use. There are many "standard sizes" you should consider.

The size of the parts of the project and the way the parts are fitted together should be correct for your design. For example, the size of a table leg should be just large enough to give the strength needed. To make it larger will waste material and cause a "clumsy" appearance. Be sure the joints will provide enough strength to hold the parts together.

Ask yourself some of these questions about your project design: What will it be used for and will it serve this purpose? Is it constructed in the simplest and most practical way? Are the sizes and kinds of material the best for this design? Will it fit into the surroundings where it will be used? Will it be easy to use and care for? Will it look as good to me next year as it does now?

MAKING A PICTORIAL SKETCH

As you work with your project ideas, pictorial sketches will help you record your ideas. They do not take long to make, and are a good way to show your instructor what you have in mind as you secure his approval and suggestions.

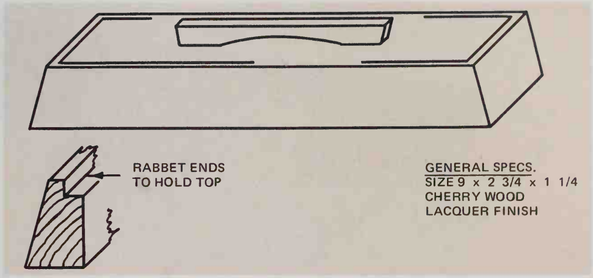


Fig. 1-3. Pictorial drawing of a card box.

One of the simplest forms of pictorial drawing is called cabinet drawing. An example is shown in Fig. 1-3. First make a profile view or front view, and then secure the third dimension (picture effect) by drawing back at an angle. Show only the outline that you can see. Make the lines drawn at an angle only about half their actual length. Pictorial views are hard to dimension and it is usually easiest to list the over-all sizes in note form as shown in the example.

You will probably need to make several drawings before you have one that is satisfactory. As you make a second drawing, use the procedure of tracing the best part of your first drawing. If you make this "overlay" with a good grade of bond paper you will be able to see the lines of your first drawing. A standard 8 1/2 x 11 sheet of paper (draftsmen call it an A size) will be a good size for most of your work.

WORKING DRAWINGS

After you have secured approval of your project ideas, you are ready to develop a working drawing. This is a drawing such as shown in Fig. 1-4. See also Fig. 1-5. It gives complete size and shape description through the use of several views and dimension lines. Detail views (usually drawn larger) show just how the object will be put together.

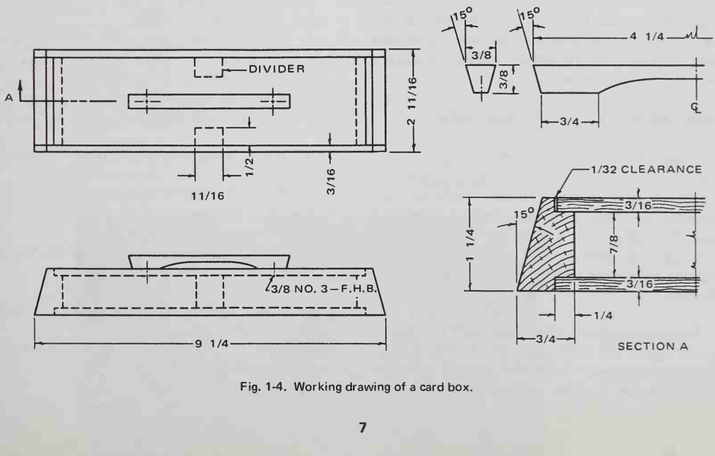


Fig. 1-4. Working drawing of a card box.

Fig. 1-5. Photograph of completed card box.

Making a good working drawing requires a lot of "know how" and skill and is a study in itself. If you need to prepare a working drawing before you have any experience in this area you should study a drawing textbook (there is one available in this series). From this study you should be able to make a rough shop sketch that will guide you through the construction of your project. Later, you may want to prepare a finished working drawing as a part of your elective work in the drawing area.

MAKING A PLAN OF PROCEDURE

A plan of procedure is a carefully prepared list of the steps you will follow in the construction of your project. It will require a careful study of your drawings to recognize the various operations and work ahead of you. This is one of the very important parts of your project plans for it will help you organize your work from day to day and prevent mistakes.

The steps should be listed in outline form. The list should not be too brief; neither should it be too long and detailed. Usually listing the exact operations and defining the part involved will be sufficient.

CARD BOX PLAN OF PROCEDURE

1. Make a stock-cutting list.
2. Select and cut out the stock.
3. Make the end pieces.
   a. Surface one side.
   b. Plane to finished width.
   c. Cut the rabbet joints while the stock is in one piece.
   d. Cut the pieces to finished length.
4. Make the sides, top and bottom.
   a. Surface rough cutting on one side if necessary.
   b. Rip to rough width and plane to finished width.
   c. Square pieces to finished length.
5. Sand the inside surfaces of all parts.
6. Glue the bottom and ends together.
7. Trim the bottom and ends if they do not line-up exactly.
8. Glue on the sides and fit the top in "dry."
9. Surface the outside of the box and cut the ends to the required angle.
10. Sand the outside surfaces. Remove the lid and sand the required clearance.
11. Make and glue in the dividers.

12. Make and attach the lid handle.
13. Remove the handle and prepare the surface for finish.
14. Apply a sealer to all surfaces.
15. Rub down sealer and apply two coats of lacquer to all outside surfaces.
16. Attach handle.

MAKING A BILL OF MATERIAL

A bill of material is a list of the things you need to build the project. The items will include: number of pieces, exact size (including joints), kind of wood and name of the part. List the dimensions of your stock in this order: thickness x width x length. The width is the dimension across the grain, the length is along the grain. A piece of stock could be wider than it is long. A complete bill of material includes hardware and finishing materials.

No.	Size	Kind	Part
2 pcs.	3/4 x 1 1/4 x 2 5/16	Cherry	Ends
2 pcs.	1/4 x 2 5/16 x 8 1/4	Cherry	Bottom & Top
2 pcs.	1/4 x 1 1/4 x 9 1/4	Cherry	Sides
1 pc.	3/8 x 3/8 x 4 1/4	Cherry	Handle
1 pc.	1/2 x 7/8 x 11/16	Cherry	Divider
2	3/8 – No. 3 – F.H.B.	Wood Screws	
	Sealer and Lacquer		

Bill of material for card box (Fig. 1-5).

A stock-cutting list can be developed from the bill of material. It is useful for estimating costs and checking out your lumber. Add about 1/16 in. to the thickness dimension if the stock must be planed. The width should be increased from 1/8 to 1/4 in. and the length about 1/2 to 1 in. Try to group the parts together as much as possible. Stock-cutting lists may vary for a given bill of material depending on the sizes of lumber that are available. A sample stock-cutting list for the card box is listed below:

No.	Size	Kind	Parts
1 pc.	5/16 x 4 x 20	Cherry	Sides, Top & Bottom
1 pc.	13/16 x 1 1/2 x 8	Cherry	Ends and Divider
1 pc.	3/8 x 3/8 x 6	Cherry	Handle

Stock-cutting list for card box.

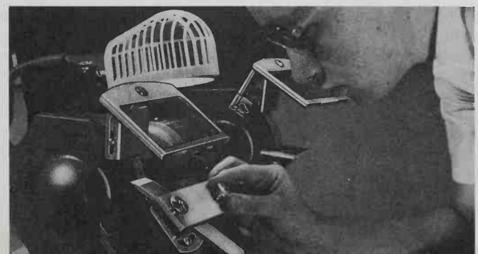
These sizes can be used to estimate the cost of the wood. The actual cost may be somewhat more, depending on sizes that are available in the stock room. For example, you may be required to purchase a 2 in. width for the second item in the list.

QUIZ – UNIT 1

(Write answers on separate sheet of paper. Do not write in this book.)

1. Planning operations in the school shop may include: selecting a project; developing the design; making a pictorial drawing; making a working drawing; making a __________ __________ __________; and developing tool and material lists.
2. A good way to improve your ability to design problems is to __________ objects that are well designed.
3. When we refer to an object as being functional, we mean that it is __________.
4. In a cabinet drawing the lines drawn at an angle are made __________ their actual length.
5. The draftsman refers to an 8 1/2 x 11 in. drawing as an __________ size.
6. A working drawing shows the exact shape and __________ of an object.

Total eye protection include's the use of safety glasses and shields along with enough good light to see what you are doing without straining your eyes.



Unit 2

SELECTING AND ROUGHING-OUT STOCK

After studying this unit, you will know:

1. **How wood is classified and graded.**
2. **How to figure the number of board feet in a piece of stock.**
3. **How to lay out rough sizes and cut them with the hand saw.**

KINDS OF WOOD

Trees are classified either as softwood or hardwood. Softwoods are the evergreen or needle-bearing trees and are often called "conifers" because many of them bear cones. Hardwood comes from broad-leafed (deciduous) trees that shed their leaves each fall. This classification is a little confusing because some of the hardwood trees produce a softer textured wood than is found in many of the so-called softwood trees.

Another classification is based on whether the wood has open or closed grain. This is determined by the size of the wood pores and makes a difference in finishing procedures.

Some of the best kinds of wood for your work in the school shop are listed below. They are all hardwoods, except white pine, red cedar and redwood. Here they are grouped according to their actual hardness.

HARD	MED. HARD	SOFT
*Walnut	*Mahogany	White Pine
*Ash	*Limba	Basswood
Birch	*Butternut	Poplar
Cherry	*Chestnut	Willow
*Oak	Gum (red)	Red Cedar
Maple	*Elm (northern)	Redwood

*Open grained wood.

The grade of lumber depends on the size of the pieces and the defects (knots, stains, checks) it contains. The best grade of hardwood lumber is first and seconds (FAS) and contains about 90 percent clear cuttings. The next lower grade is selects (sometimes called FAS 1 face) which permits smaller pieces and more defects in the second or back face (surface). The lowest grade is No. 1 common and contains about 60 percent clear cuttings.

Softwood lumber (Fir, Pine, Spruce, Redwood, etc.) handled at local lumber yards is divided into a select and common classification. Select grades range from A through D with a B, or better, the highest grade usually available. Select grades are desirable for project work. The usual grades of common lumber range from No. 1 to No. 3 and are used for house framing and other rough carpentry.

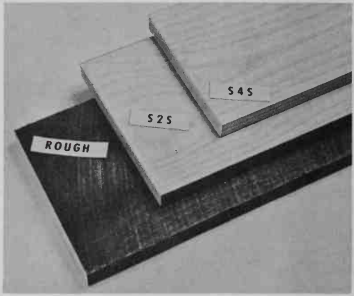


Fig. 2-1. Left. Rough lumber. Center. Surfaced 2 sides. Right. Surfaced 4 sides.

The quality of lumber is also indicated by the method of drying. Air dried (AD) lumber is simply exposed to the air over a period of time. Kiln dried (KD) lumber is dried in huge ovens where temperature and humidity are carefully controlled. Kiln dried lumber usually has a lower moisture content and is free of internal stresses that are usually present in air dried lumber. Lumber that is to be used for cabinetwork and furniture should be kiln dried.

SURFACE AND SIZE

Hardwoods can be purchased either rough (Rgh.) or surfaced on both sides (S2S), Fig. 2-1. Some of the wood is removed in the planing or surfacing operation so that a 1 in. hardwood board will actually measure 13/16 in. Hardwood lumber is usually not planed on the edges and is sold in random widths and lengths with only the minimum sizes specified.

Softwoods are surfaced on all faces and edges (S4S) and are sold in specified widths from 2 to 12 in. by 2 in. intervals and in lengths of 8 to 20 ft. by 2 ft. intervals. A 1 x 4 will actually measure 3/4 x 3 1/2 in. The width of (S4S) lumber is reduced by 1/2 in. for pieces 6 in. and under. Over 6 in. the reduction is 3/4 in.

Lumber is always listed and sold according to its nominal (name) size. This is the size of the stock when it was "in the rough." It will be good practice for you to use this nominal size as you list and work with stock in the school shop.

ROUGH AND FINISHED SIZES

SOFTWOODS		HARDWOODS	
RGH. (NAME SIZE)	S4S	RGH. (NAME SIZE)	S2S
1 x 2	3/4 x 1 1/2	1/2	5/16
1 x 4	3/4 x 3 1/2	5/8	7/16
1 x 6	3/4 x 5 1/2	3/4	9/16
2 x 4	1 1/2 x 3 1/2	1	13/16
2 x 6	1 1/2 x 5 1/2	1 1/2	1 5/16
2 x 8	1 1/2 x 7 1/4	2	1 3/4

PLYWOOD

Plywood is available in nearly all of the hardwoods. Fir plywood is the most common of the softwoods. Thicknesses of 1/8 in. to more than 1 in. are made with the more common sizes including 1/4, 3/8, 1/2 and 3/4 in. A standard panel size is 4 ft. wide by 8 ft. long, however, many smaller sizes are offered for sale, especially in the hardwoods. Plywood is constructed of an odd number of ply – 3, 5, 7 – with the direction of the grain reversed in each successive layer. The outside layers are called face and the inside layers are called the core. The best hardwood plywood is constructed with a thick solid stock for a core (called a lumber core), Fig. 2-2.

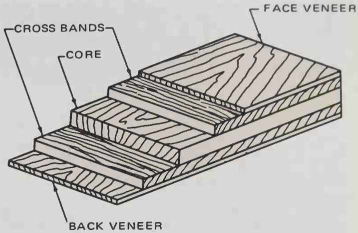


Fig. 2-2. Plywood construction.

In general the grade of plywood is determined by the quality of the face veneers. Hardwood plywood may be of good quality on both sides (G2S) or of good quality on only one side (G1S). The grade of a face varies with the quality of the veneer and the way it is cut and matched. The face veneer grades of softwood plywood range from A through D. The best piece of softwood plywood available would be an AA grade.

FIGURING BOARD FOOTAGE

Lumber is sold by the board foot. This is a piece that is 1 in. thick and 12 in. square (144 cu. in.). To figure the number of board feet in stock the following formula is used.

$$BF = \frac{\text{No. Pcs.} \times T \times W \times L}{1 \times 12 \times 12}$$

For an example: find the number of board feet in 2 pcs. of wood that are 1 x 8 x 48.

$$BF = \frac{2 \times 1 \times \overset{2}{\cancel{8}} \times \overset{4}{\cancel{48}}}{1 \times \underset{3}{\cancel{12}} \times \underset{1}{\cancel{12}}} = \frac{16}{3} = 5\ 1/3$$

Stock that is less than 1 in. thick is figured as though it were 1 in. When the stock is thicker than 1 in. the nominal size is used. When the thickness is over one inch and includes a fraction such as 1 1/2, change it to an improper fraction (3/2) and place the numerator above the line and the denominator below the line. Example: find the board footage in one piece of stock, 1 1/2 x 10 x 36.

$$BF = \frac{1 \times \overset{1}{\cancel{3}} \times \overset{5}{\cancel{10}} \times \overset{3}{\cancel{36}}}{\underset{1}{\cancel{2}} \times 1 \times \underset{4}{\cancel{12}} \times \underset{1}{\cancel{12}}} = \frac{15}{4} = 3\ 3/4$$

Always use the nominal size of lumber to figure board footage. If the stock is long and the length is given in feet then one of the twelves (12s) can be dropped from the lower half of the formula.

Plywood is sold by the square foot in standard size panels. Prices vary for different thicknesses, kinds and grades.

SELECTING AND LAYING OUT

After you have made a stock-cutting list you are ready to look over the lumber stock and select a piece for your project. This requires good judgment. You may need the help of your instructor.

Look the stock over carefully on both sides and make a rough layout of the pieces you need, using a bench rule or a template, Fig. 2-3. White chalk works well since it is easily wiped off if you want to try other arrangements, Fig. 2-4. These will not be used for finished cutting but only to help you see how the piece will be cut up after it has been planed.

Be sure to look at the end of the stock. If the end is rough as it came from the sawmill, it will have small splits and checks that must be trimmed. It's very poor economy to cut stock and then find later that it contains defects that interfere with its use.

Fig. 2-3. Using template to determine size of rough cutting.

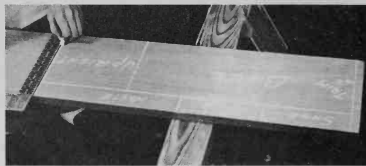


Fig. 2-4. Using chalk to make rough layout.

Some wood defects can be covered or placed on the back of your project. Very tight knots may even be desirable because of the beautiful grain patterns that are present around them.

Check your layout carefully to see that you have allowed: 1/16 in. thickness for planing, about 1/4 in. for each width you must cut out and about 1/2 to 1 in. for each length. Be sure the grain is running in the right direction in each piece. Use the framing square to mark a line across the stock as shown in Fig. 2-4.

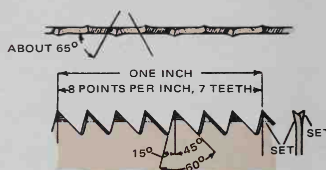


Fig. 2-5. Crosscut saw teeth. (Stanley Tools)

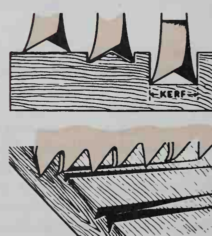


Fig. 2-6. How the teeth of a saw cut. (H. K. Porter Co.)

WOODY SAYS:

"When starting the saw cut, keep your thumb high on the blade so if the saw should jump out of the kerf you will not cut yourself."

CUTTING STOCK TO ROUGH LENGTH

Select a crosscut saw that has 8 to 10 points per inch. Fig. 2-5 shows the shape of crosscut saw teeth. The set causes the saw to cut a "kerf" that is wider than the thickness of the blade, thus permitting it to move freely through the work, Fig. 2-6.

Support stock either in a bench vise or on sawhorses. Hold the saw in your right hand (if you are right handed) and place your left hand on the board, using your thumb as a guide to start the saw blade. Start the cut by pulling the saw toward you several times.

As soon as the saw is started, move your left hand away from the blade and hold the saw at about a 45 deg. angle, as shown in Fig. 2-7. If the saw starts to cut away from the line you can bring it back by twisting the blade slightly. Use long full strokes, feeding the saw into the cut with a slight pressure. Slow down as you near the end of the cut and support the wood so you will not split the corner. Be careful not to cut into the sawhorses or bench.

Plywood should be laid out and cut very carefully. It is best to make a scaled layout on paper if the parts are complicated. Lay out only the cutting lines since a plywood surface is already sanded and nearly ready for finish. Use a fine-tooth crosscut saw for all the cutting. Try to avoid splintering along the underside of the kerf.

RIPPING STOCK TO ROUGH WIDTH

If a piece is small, a crosscut saw can be used to rip it to width. A ripsaw which has chisel-shaped teeth will rip stock much faster than a crosscut saw and should be used on larger jobs.

Use the same general procedure for cutting with a ripsaw as described for the crosscut saw. The ripsaw works best when it is held at a 60 deg. angle with the surface of the work. A ripsaw should not be used for cutting plywood. Refer to Figs. 2-8 and 2-9.

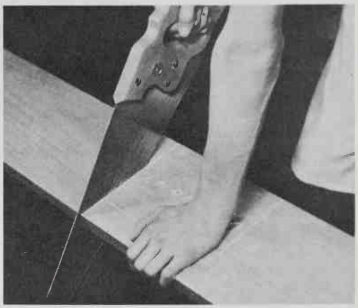


Fig. 2-7. Cutting stock to rough length.

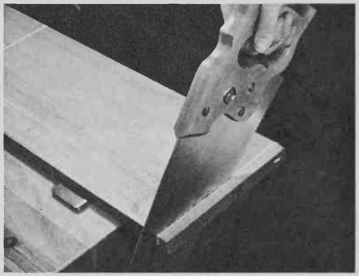
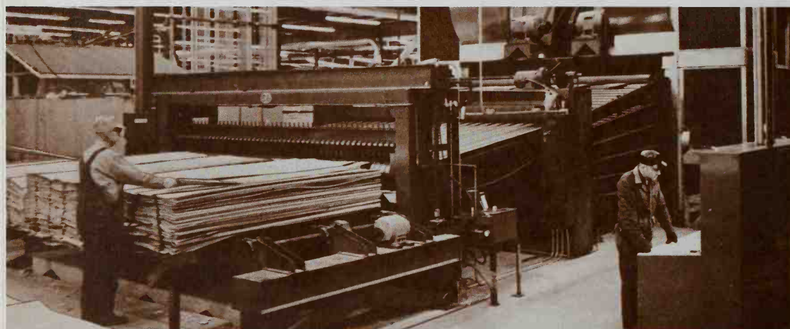


Fig. 2-8. Trimming on end with the stock clamped between the vise dog and bench stop.

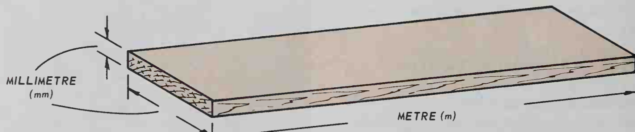
Fig. 2-9. Ripping to rough width with the stock clamped in a vise.

QUIZ – UNIT 2

1. Softwood trees are often called __________ because many of the trees in this classification bear cones.
2. The second best grade of hardwood lumber is called ____________.
3. The third best grade of hardwood lumber is called No. 1 Common and contains about _____ percent clear cuttings.
4. Softwood lumber that is handled by local lumber yards is divided into a select grade and a _____ _____ grade.
5. One inch hardwood lumber is surfaced (S2S) to a thickness of __________.
6. A piece of 2 x 6 fir would actually measure 1 1/2 in. by _____ in.
7. When hardwood plywood is good on both faces the symbol __________ is used in the description.
8. The grade of the faces of softwood plywood are indicated by the letters A through __________.
9. There are __________ board feet in a piece of lumber 1 in. x 9 in. x 54 in.
10. There are __________ board feet in a piece of lumber that is 1/2 in. x 8 in. x 5 ft.
11. If 1 1/2 in. walnut is selling for 60 cents a board foot, a piece 4 in. x 36 in. will cost _____.



Drying and sorting veneer in modern plywood manufacturing. Infeed end of huge dryer is over 100 ft. long. Automatic mechanism distributes individual sheets to one of several conveyor levels. Carefully controlled temperatures (up to 360 deg. F.) and air movement reduce the MC (moisture content) to the desired level in about 10 minutes. (Georgia-Pacific Corp.)



NOMINAL SIZES (PARTIAL LIST)

THICKNESS		WIDTH		LENGTH	
1/2 IN.	13 mm	4 IN.	100 mm	6 FT.	1.8 m
3/4 IN.	19 mm	5 IN.	125 mm	7 FT.	2.1 m
1 IN.	25 mm	6 IN.	150 mm	8 FT.	2.4 m
1-1/2 IN.	38 mm	8 IN.	200 mm	10 FT.	3.0 m
2 IN.	50 mm	10 IN.	250 mm	12 FT.	3.6 m

Standard lumber sizes in U.S. Customary and SI metric (also see pages 116 and 117).

Unit 3

PLANING AND SAWING STOCK TO FINISHED DIMENSIONS

After studying this unit, you will know:
1. **How to sharpen and adjust a plane.**
2. **How to use the plane on surfaces and edges.**
3. **How to cut stock to finished length with a backsaw.**

THE PLANE AND ITS PARTS

If you examine a catalog of hand tools you will find many types and sizes of planes. This list would include such names as Smooth, Jack, Fore, Jointer, Block, Rabbet, Circular, Router and Model Builders. For your work in squaring up stock you should use a smooth plane and/or a jack plane and a block plane. A smooth plane is shown in Fig. 3-1. It is usually 8 or 9 in. long. The jack plane is the same type but larger, ranging in length from 11 1/2 to 15 in. The standard model is 14 in. long and has a 2 in. cutter.

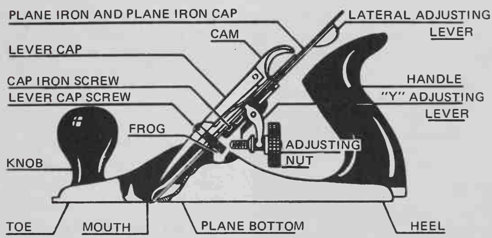


Fig. 3-1. Parts of a standard plane.

The plane is a tool with which you should become well acquanited. Take your plane apart and study it along with Fig. 3-1, so that you will know the name of its parts, and how they fit together.

HONING PLANE IRON

Sharpening a plane iron involves operations called grinding and honing. Grinding is the shaping and forming of the cutting edge and bevel. Honing involves work on only the cutting edge to make it "razor" sharp. An edge tool can usually be honed a number of times before it requires grinding.

Apply a few drops of oil to the face of an oilstone and place the bevel of the plane iron flat on the surface. Now raise the end slightly so that just the cutting edge rests on the stone. Maintain this angle and move the plane iron forward and backward over the surface of the stone, as shown in A, Fig. 3-2.

Continue these strokes until you can feel a fine wire edge when you move your finger, lightly, across the top of the plane iron and out over the edge. Turn the plane iron over, lay it flat on the stone and stroke it a few times as shown in B, Fig. 3-2.

Turn the iron back to the bevel side and give it a few light strokes and then again stroke the top of the iron held flat on the stone. Repeat this several times

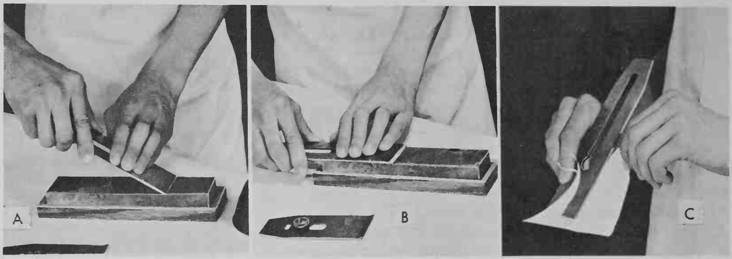


Fig. 3-2. Honing the plane iron.

until the wire edge has disappeared. The edge will now be sharp and "keen" and should cut a piece of paper as shown in C, Fig. 3-2.

When you finish with the oilstone, wipe the oil from the surface and replace the cover.

GRINDING A PLANE IRON

Fig. 3-3 shows the grinding of a plane iron held in a special attachment that makes it easy to form a perfect bevel. Position the iron carefully in the clamp so that the width of the bevel ground will be about two and one-third times the thickness of the plane iron. Move the iron back and forth across the revolving wheel until the edge is so thin that a burr starts to form. Grind just a little heavier on the outside corners so that the cutting edge will be about 1/32 in. higher in the center. Some woodworkers prefer to form this slight crown on an oilstone.

Fig. 3-3. Grinding a plane iron. (Stanley Tools)

During the grinding, keep the plane iron cool by dipping it in water. If the grinder does not have an approved eye shield, you must wear goggles to protect your eyes.

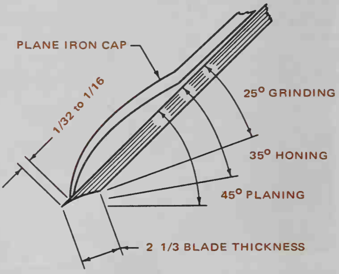


Fig. 3-4. Double plane iron assembled.

ADJUSTING THE PLANE

Position iron cap on the plane iron as shown in Fig. 3-4 and tighten the cap iron screw. The edge of the plane iron cap must fit tight against the top of the plane iron, otherwise shavings will feed under it and prevent the plane from cutting properly.

Carefully place this assembly (often called a double plane iron) into the plane and secure its position with the lever cap. If necessary, adjust the setting of the lever cap screw so that the cam of the lever cap locks in place with a smooth firm pressure.

Turn the plane upside down and sight across the bottom, looking toward a window or other source of light. Turn the adjustment nut clockwise until the blade projects above the plane bed about 1/16 in. Now move the lateral adjustment lever from side to side until the cutting edge is parallel to the bottom face of the plane. Turn the adjustment nut counter-clockwise until the cutting edge is withdrawn below the surface of the plane bottom. Place the plane on the surface of the stock and again turn the adjustment nut clockwise until the plane edge just begins to cut the stock.

PLANING A SURFACE

If you will look closely at the surface of some solid stock you will find there are very small "waves" (called mill marks) which were formed by the rotating knives of a power plane. Fig. 3-5. These should be removed with a hand plane. It takes a great amount of hand sanding to remove such marks, and since they are slightly compressed into the wood by the machine, there is a tendency for them to reappear when finish is applied. Hand planing will also remove warp and other imperfections in the surface of the stock. See Fig. 3-6.

Plane the best face of the stock first. By examining the edge of the board try to determine the direction of the grain and clamp the stock in position so that you will be planing with the grain. Most stock can be laid flat on a bench and clamped between a bench stop and vise dog.

Place the plane on the stock and move it over the surface, gradually turning the adjustment nut until a fine shaving is cut. You may find that the plane cuts in some spots and not in others. This indicates high places in the surface. Continue to plane these high spots until they disappear and the plane "takes" a shaving across the entire surface. Keep the plane set for a very fine cut. The shavings should be light and "feathery" and should seem to almost float when you drop a handful to the floor. Try to produce a smooth, true surface with as little planing as possible.

Generally, it is considered best to plane the surface of your stock while it is in one piece and before it is cut into smaller parts. If, however, there is much warpage present, you should cut the stock into smaller pieces before hand planing. Warped stock can be straightened by planing across or diagonally with the grain.

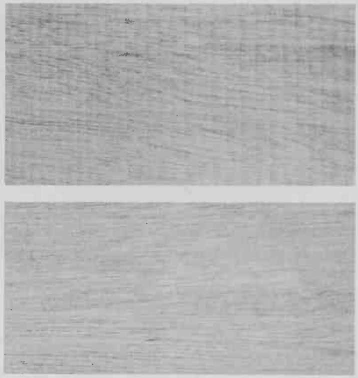


Fig. 3-5. Above. Mill marks on stock surfaced with a power plane. Below. Surface after hand planing.

Turn the stock end over end and plane the other side. Measure the stock at several points to determine finished thickness.

Fig. 3-6. Planing a surface with a smooth plane.

On some work the hand surfacing operation should be done later. If it is necessary to make edge joints to secure the required width of stock, then the hand surfacing operation should be left until after these joints have been made. In Fig. 3-7, the outside surfaces of the box are being planed, after the box was glued together.

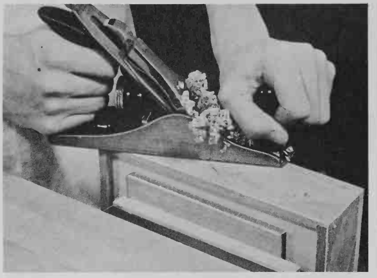


Fig. 3-7. Planing the sides of a box after assembly.

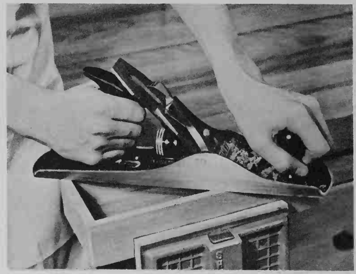


Fig. 3-9. Planing edge of assembled project.

PLANING AN EDGE

In Fig. 3-8 a jack plane is being used to plane the edge of the stock. Notice that one end is held in the vise, and the other is supported by a hand screw that rests on the bench surface. Select the best edge to plane first, since slight defects on the second edge may be removed when the stock is reduced to the required width. A smooth plane may be used to plane the edge; however, the longer bed of the jack plane will produce a straighter surface.

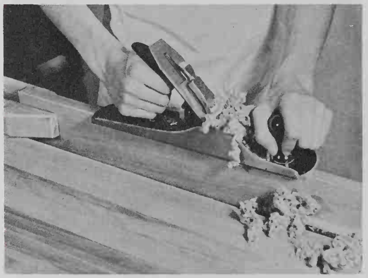


Fig. 3-8. Planing an edge with a jack plane.

In planing an edge, use the same suggestions as were made for planing a surface. Fig. 3-9. Continue to plane the edge until the plane will take one thin, continuous shaving the entire length of the board. Use a try square to check the edge for squareness with the best face.

From the finished edge, lay out the required width and draw a line down the length of the stock. Turn the stock end over end and plane to the line. Some woodworkers prefer to square the ends to finished length before planing the second edge.

SQUARING END OF STOCK

You can secure an accurate end cut by following the procedure shown in Fig. 3-10. Clamp the straight edge firmly along the line to be cut. Tighten the outside spindle of the hand screw last since it provides the greatest leverage.

Place the blade of the backsaw against the straightedge and start the cut. With the left hand, apply pressure to the side of the saw so the blade will be held firmly against the straightedge throughout the cut. The teeth of a backsaw are small (14 points to the in.) and will not cut very fast. Use long steady strokes. Sawdust cut near the center of the board must be moved to the edge of the stock, before it can be cleared from the saw kerf. Short strokes will not clear the sawdust and it will work up along the sides of the saw and cause the blade to bind. Notice that the stock is clamped to a scrap piece that protects the saw from the vise and supports the wood fibers on the under side of the cut.

From the squared end lay out the finished length. Use the same procedure to cut off the second end. Whenever possible, clamp the straightedge on the

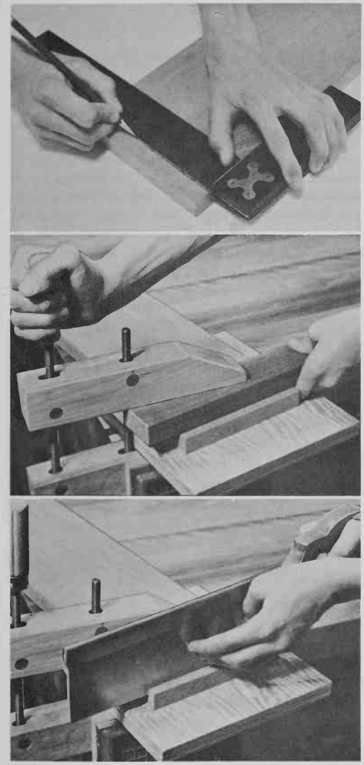


Fig. 3-10. Squaring end of stock. Above. Marking with a pencil and try square. Center. Clamping a straightedge along the line. Below. Making the cut with a backsaw.

stock so that the saw kerf will be on the "waste" side of the line. If you cannot do this, you will need to make an allowance for the width of the saw kerf.

PLANING END GRAIN

End grain is hard to plane. Because of this, it is usually worth while to give extra attention to saw cuts across the grain, so that they will be square and not require planing. End grain that will be exposed in the finished project should be planed.

Fig. 3-11. A block plane. (Stanley Tools)

In end planing, a block plane will do the best work, Fig. 3-11. In this plane, the blade sets at a low angle with the bevel side turned up. It makes a "shearing" type of cut. The block plane is designed to be held in one hand, leaving the other hand free to hold or support the work. It will do all kinds of small planing jobs, and is useful for trimming the edges of plywood.

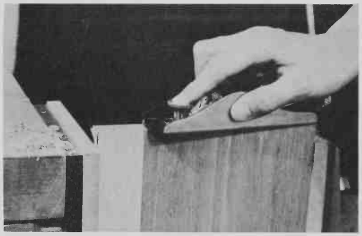


Fig. 3-12. Planing an end with the block plane. The waste stock (light wood) supports the edge, and prevents splitting.

When planing end grain, the cut should not carry over an edge or end unless the wood fibers are supported as shown in Fig. 3-12. When the board is wide it is easiest to plane in from each edge, toward the center. It is recommended to use a very light cut when planing end grain.

SQUARING SMALL PARTS

Small parts are often difficult to plane and saw. They are hard to clamp and hold and the regular tools seem large and "clumsy."

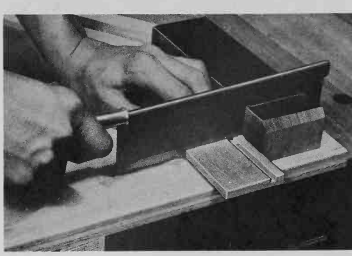


Fig. 3-13. Squaring small parts with the dovetail saw and a special jig.

Fig. 3-13 shows a jig that works well for sawing small parts. It clamps in the vise like a bench hook, and works in about the same way as a miter box. The dovetail saw being used has a thin blade, very fine teeth and makes a smooth cut. A regular backsaw will also work satisfactorily. When constructing the jig, the block that guides the saw is cut in two pieces and then glued to the base with the saw in position. A little paste wax, applied to this "kerf" or slot will make the saw run smoothly.

Jigs like this are not difficult to build and will help you do a better job. You may want to "try your hand" at designing some kind of a jig for some special construction problem. Industrial plants use many jigs and fixtures to provide speed and accuracy in their work.

Sanding should usually not be started until all tool operations are complete. Small parts, however, can be squared quickly and easily on the sanding board shown in Fig. 3-14. The straightedge must have faces and edges that are square with each other. Grip the block being squared close to the sandpaper surface, otherwise it will tend to tip over. The straightedge could be made at an angle to sand some special part.

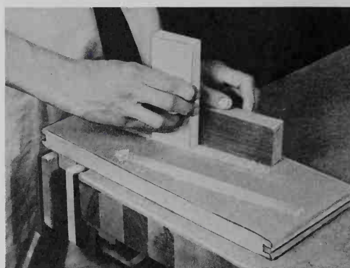


Fig. 3-14. Using a sanding board and a straightedge to square a small piece.

QUIZ – UNIT 3

1. A ________ plane is about 8 or 9 in. long.
2. The opening in the bottom of the plane through which the plane iron extends is called the ________ .
3. The double plane iron assembly is held in the plane with the ________ .
4. A right-handed worker holds the ________ of the jack or smooth plane in his left hand.
5. A plane iron should usually be sharpened so that the edge is about ________ higher in the center.
6. The width of the bevel ground on the plane iron should be about ________ times the thickness of the blade.
7. To increase the depth of cut of a jack plane, the ________ ________ is turned clockwise.
8. The small waves left on a wood surface by the power planer are called ________ .
9. To line up the edge of the plane iron with the surface of the plane bottom, the ________ adjustment is moved.
10. Sharpening operations for an edge tool include grinding and ________ .
11. To secure the greatest pressure from a hand screw the ________ spindle should be tightened last.
12. The backsaw has teeth which are small and number about ________ points to the inch.

Unit 4
MAKING WOOD JOINTS

After studying this unit, you will know:
1. **Some of the common types of wood joints.**
2. **How to lay out and plane an edge joint.**
3. **How to use a straightedge and jig to cut rabbet and dado joints.**

There are a great many kinds of joints used to connect wood parts. Some of the basic types are shown in Fig. 4-1. Most wood joints are held together with glue. Strength of the joints depends on the amount of contact area (the surface of one piece touching the other piece) and the quality of the glue job. Joints that do not have much contact area are usually reinforced with nails, screws, dowels or other fastening devices.

The pieces to be joined should first be squared and cut to size. For some joints you will need to allow extra stock to form the joint. Lay out the cuts carefully, using a sharp pencil or knife. When possible, it is good practice to mark one piece by holding the second piece over it and in the correct position. Lay out all the same kind of joints at one time. Sometimes this is done by clamping identical pieces together. Identify the two members of a given joint with a number or letter so that they can be easily matched during assembly.

BUTT AND EDGE JOINTS

A butt joint that is held together with glue is not very strong and should be reinforced with dowels, nails or screws. Usually it is best to clamp the parts of a butt joint together, while driving nails or setting screws. A doweling jig can be used to position and guide the bit when drilling holes for dowels.

The edge joint holds securely with glue but can be reinforced with dowels or splines. It is used to join narrow pieces to form wider widths. Lay out the pieces to be joined so the grain is matched, and runs in the same direction. The annular ring pattern should be reversed in every other piece as shown in Fig. 4-2. After the position of the pieces has been determined, make reference marks on the top surface.

Planing an edge joint (Fig. 4-3) requires careful work. Clamp two adjacent pieces together in a vise with the top surfaces (marked) turned to the outside.

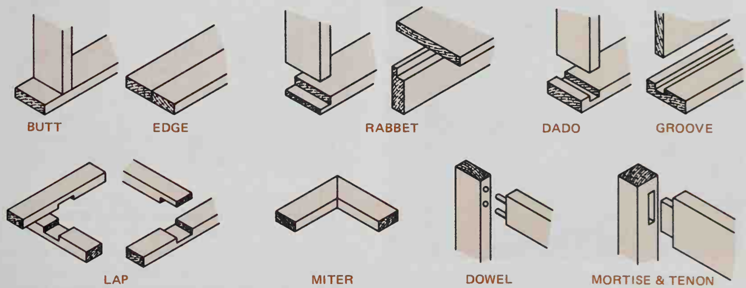


Fig. 4-1. Wood joints.

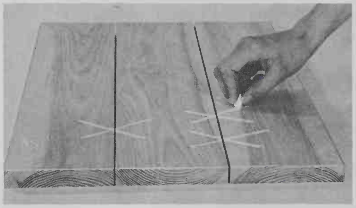


Fig. 4-2. Selecting and marking edge joints. Notice that the grain pattern has been matched and the annular rings are reversed in adjoining pieces.

Plane the edges until you are able to take a light, thin shaving along the entire length. Remove the pieces from the vise and place them together to check the fit. Slight variations in the joint can now be corrected by planing each piece separately. Have your instructor check the joint. Next, refer to Unit number 7 for suggestions on gluing the pieces together.

To install dowels in the edge joint, clamp the two pieces in the vise (top surfaces on the outside) with the edges and ends even. Square lines across the edge where each dowel will be located. Dowels should be spaced about 4 to 6 in. apart. The diameter of the dowel should be equal to one half the thickness of the stock.

A doweling jig (Fig. 4-5) makes it easy to bore the holes. Mount a bit guide of the correct diameter in

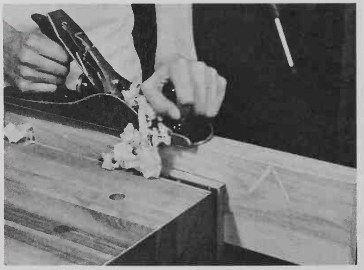


Fig. 4-3. Planing an edge joint. Both pieces are clamped in the vise with the top faces turned to the outside.

the jig and position the holder so it is in the center of the stock. Place a depth gage on the bit to provide a hole 1/16 in. deeper than half of the dowel length. In a dowel joint the dowels should enter each piece of wood a distance equal to about two and one half times their diameter.

Line up the jig with the layout mark, clamp it securely and bore the hole. Turn the jig around so the fence is on the other side, align with the mark and bore the matching hole. Follow the same procedure and bore all the other holes before removing the pieces from the vise.

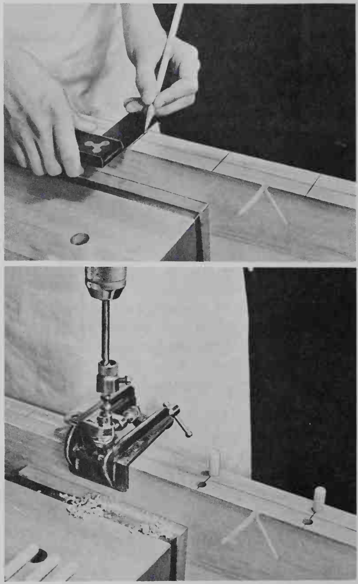


Fig. 4-4. Installing dowels in an edge joint. Above. Laying out the position of the dowels. Below. Boring holes with the doweling jig.

The edges of flooring and siding are joined with a tongue and groove or lap joint. In production

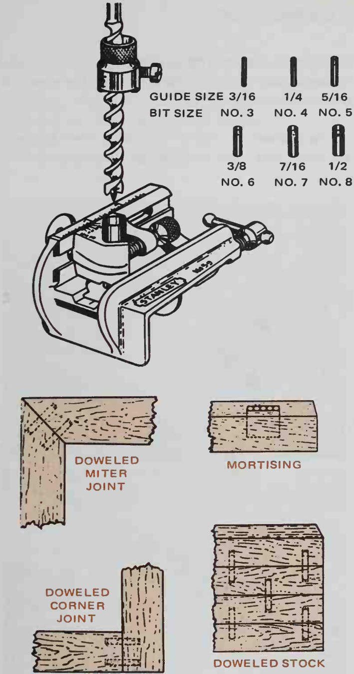


Fig. 4-5. A doweling jig and doweled joints. (Stanley Tools)

woodwork, edges that will be glued together are often cut with a multiple tongue and groove.

RABBET JOINTS

The rabbet joint is made by cutting a recess in one of the pieces to be joined. It may be cut along the edge or on the end of the stock, and is a good joint for mounting panels in frames or joining corners in box construction. The width of a rabbet joint is equal to the thickness of the mating part and the depth should be about two thirds of the thickness of the stock being cut. When working with plywood a greater depth is often used so very little of the edge of the plywood will show in the assembled joint.

The jig shown in Fig. 4-6 will help you make an accurate cheek (end grain) cut. A thin strip (thickness determined by the size of the joint) is glued to a piece of flat stock. Clamp the jig in the vise and then clamp the work to the jig with a hand screw. The backsaw is held firmly against the jig while the cut is being made.

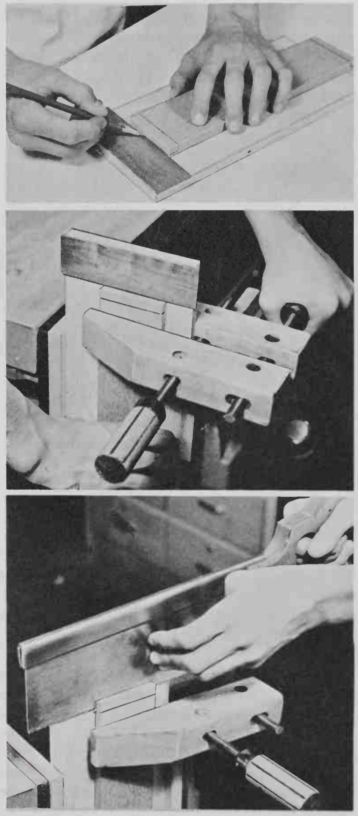


Fig. 4-6. Cutting a rabbet joint. Above. Using a jig to lay out the joint. Center. Clamping the stock to the jig. Below. Making the cheek cut with the backsaw.

The shoulder cut is made by clamping a straightedge along the line, in the same manner as was suggested for squaring the end of stock. You can check your layout by placing the mating pieces against the straightedge and checking to see if it lines up with the end of the stock being cut. Use a wood chisel to trim or straighten the surfaces of the joint.

When cutting a rabbet along the edge of stock it is best to use a rabbet plane as shown in Fig. 4-7. This plane has an adjustable fence and depth gage that controls the width and depth of cut. Adjust the controls of the plane and practice cutting a rabbet in a piece of scrap lumber before using it on your work.

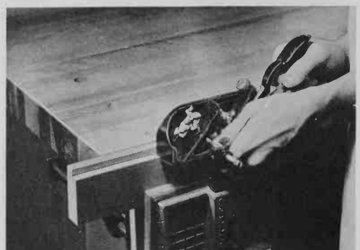


Fig. 4-7. Using a rabbet plane to cut a joint with the grain.

DADOS AND GROOVES

A dado is a rectangular recess cut in the wood and running across the wood grain. A groove is the same type of cut but runs along the grain of the wood. Both the dado and the groove are cut to a depth equal to one half the thickness of the stock.

Lay out the dado on the face and edges of the stock. Clamp a straightedge along one of the lines so that the kerf will be on the waste side and then make a cut to the proper depth with a backsaw. Move the straightedge to the other line and clamp it lightly. Place the part that will fit into the dado (mating part) against the straightedge and align its surface with the outside edge of the first saw cut. If you make this adjustment carefully you will get a perfect fit. Now clamp the straightedge securely, remove the mating part and make the second cut. On wide boards, use long strokes, so that the saw dust that is cut in the center of the piece, will be carried to the edge and removed from the saw kerf.

Use a chisel to remove the waste wood between the saw kerfs. The straightedge should be left in

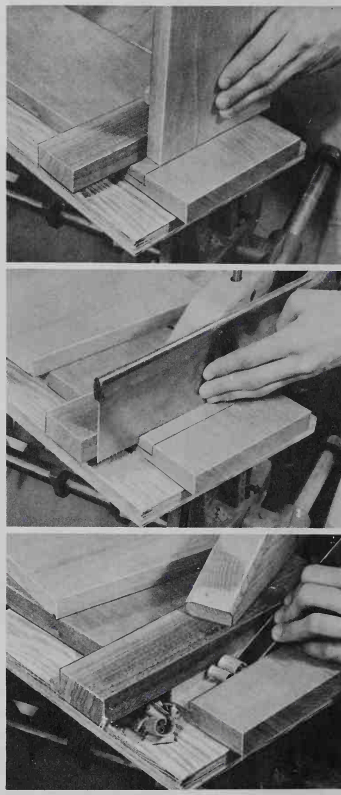


Fig. 4-8. Cutting a dado joint. Above. Setting the straightedge for the second saw cut. Center. Making the second cut with the backsaw. Below. Using a 3/4 in. chisel to remove the waste stock.

place, since it will serve as a guide for the chisel as shown in Fig. 4-8. Rough cuts should be made with the bevel of the chisel turned down or against the wood. For fine, finished cuts this position is reversed.

The dado can be finished with a router plane as shown in Fig. 4-9. This will make the bottom of the dado level and true. Make the cuts in from each side toward the center to prevent splitting the edges of the joint.

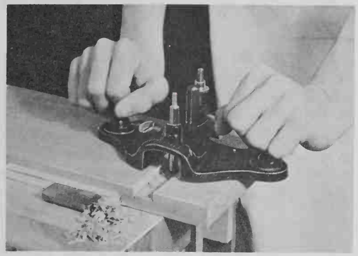


Fig. 4-9. Finishing dado joint with router plane.

Grooves are cut in about the same way as dados. The marking gage can be used to lay out the groove and is especially helpful on long pieces. Use a straightedge to guide the saw when cutting the sides of the groove. The panel or mating part will help to position the straightedge for the second cut.

Use a chisel that is about the same width as the groove to remove the wood from between the saw kerfs. A router plane can be used to finish the bottom of the groove.

The final trimming and fitting of grooves and dados can be done with a chisel. Lay the chisel flat on the work with the bevel turned out when making light, paring cuts. If the joint is too tight it is often easier to plane off the necessary thickness of the mating piece than to enlarge the width of the dado or groove. See Fig. 4-10.

LAP JOINTS

In the lap joint an equal amount of wood is removed from each piece. There are a number of different types of lap joints with such names as end lap, half lap, edge lap, and the cross lap and middle lap as shown in Fig. 4-1.

Lap joints are easy to lay out, using a try square and a marking gage. Or, you can lap the two pieces to be joined and, along the edge of each piece, mark lines on the face of the other piece.

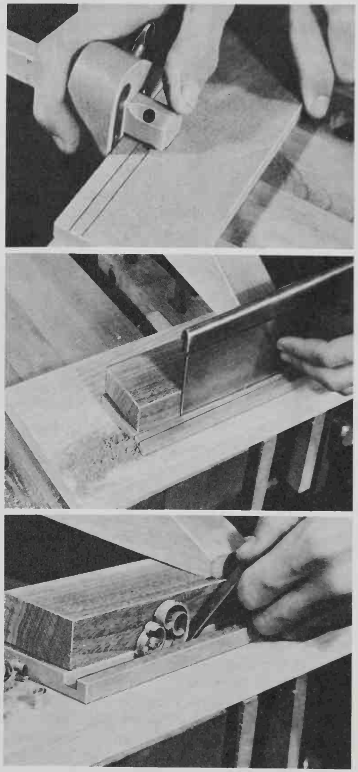


Fig. 4-10. Cutting a groove. Above. Using a marking gage for the layout. Center. Making the second cut with the backsaw. Below. Using a 1/4 in. chisel to remove waste stock.

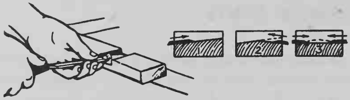


Fig. 4-11. Using the chisel to remove waste stock from a lap joint.

Use the same procedures for sawing and removing the waste stock as was described for cutting the rabbet and dado joints, Fig. 4-11. If the joint is very wide, it may be helpful to make several saw cuts in the waste stock. When the joint fits too tight, it may be easier to reduce the width of the pieces, rather than to trim the shoulder cuts.

MITER JOINTS

The miter joint is formed by cutting an equal angle (usually 45 deg.) on each of the mating parts. It is an attractive joint since none of the end grain of the parts is visible. The miter joint does not have much strength and is often reinforced with wood or metal splines or dowels.

The miter box shown in Fig. 4-12 is designed especially for cutting angles. Swing the saw carrier to the 45 deg. position, and hold the stock firmly on the bed and against the back. For very accurate work, the stock should be clamped in position, either with a hand screw or special clamps provided on some miter boxes. Use long steady strokes while making the cut. The weight of the saw will be sufficient to feed it into the work. On small pieces it may be necessary to "hold up" on the saw so that it will not cut too fast.

MORTISE-AND-TENON JOINTS

The mortise-and-tenon joint is very strong, and is used in the construction of quality furniture and cabinetwork. Making this joint by hand requires considerable skill. You should not attempt it until you have had successful experience making some of the other joints described in this section.

Study a number of good working drawings showing mortise-and-tenon joints, before designing and laying out your own. The thickness of the tenon is usually one half the thickness of the stock but other dimensions may vary widely depending on how the joint is used. When laying out several joints it is best to clamp similar pieces together and square lines across all of them at the same time.

The mortise is cut first by boring a series of holes within the layout lines. A doweling jig will be helpful

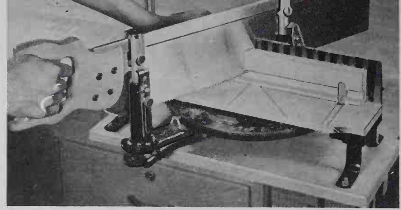


Fig. 4-12. Using a miter box.

in this operation. A chisel is used to remove the remaining waste stock and to trim the corners and sides.

Check the size of the tenon layout against the mortise that has been cut, and adjust if necessary. Use a jig to make the cheek cuts (similar to the one used for the rabbet joint). When all of the cheek cuts are complete, make the shoulder cuts by clamping a straightedge along the line to be cut. If you are making a number of joints, you may want to design a special jig to speed up your work on these cuts.

When you select a joint that is hard to make, like the mortise-and-tenon joint, you should make a sample joint out of scrap wood before making the joints for your project.

QUIZ – UNIT 4

1. The layout lines of a joint can be made with a pencil or ________ .
2. A butt joint is usually held together with dowels, nails or ________ .
3. When making edge joints to form a wide board it is important that the ________ ________ be reversed in every other piece.
4. The diameter of the dowels installed in an edge joint should be equal to ________ the thickness of the stock.
5. The hole for a dowel should be drilled about ________ in. deeper than the dowel length will require.
6. The depth of a rabbet cut in 3/4 in. stock should be about ________ .
7. The depth of a dado cut in 5/8 in. stock should be ________ .
8. When laying out a groove in a long piece it is best to use a ________ .
9. The bottom of a dado joint can be leveled and finished with a ________ .
10. When making a mortise and tenon joint the ________ should be made first.

Unit 5

FORMING CURVES, CHAMFERS, BEVELS

After studying this unit, you will know:

1. **How to lay out curves and make patterns and templates.**
2. **How to cut irregular shapes and smooth the edges.**
3. **How to lay out and cut chamfers, bevels, and tapers.**

Many articles made of wood contain curves and irregular shapes. The layout for some of these can be made directly on the wood, while for others it is necessary to develop a pattern and then transfer it to the wood.

The surface of solid stock should be hand planed before laying out and cutting irregular shapes. Since curved pieces are hard to clamp and hold, it is advisable to make joints and bore holes before cutting out the curved parts. Pieces that have only one or two curved edges should be squared to finished size with the saw and plane, before the curved edges are cut.

CIRCLES AND ARCS

Circles and arcs (part of a circle) can usually be laid out directly on the work using dividers or pencil compass. For large circles you can use the trammel points or a pencil attached to a piece of string. See Fig. 5-1.

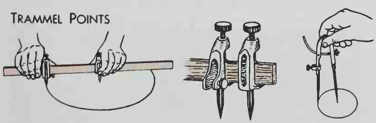


Fig. 5-1. Trammel points and dividers.

Set the dividers at one half the diameter of the circle, and place one leg at the center point. Tilt the dividers slightly in the direction of movement as you draw the circle; be sure to hold a piece of cardboard under the center leg for protection if it is located on a finished surface.

Using a compass, many geometric shapes can be developed. You probably have already had experience making a hexagon (6 sides) by laying off the radius of a circle around the circumference and connecting these points with a straight line.

CURVES

A smooth flowing curve is usually more interesting than a perfect circle or arc. These are the kind of curves that we see in the contour of airplanes, boats and automobiles. The engineer and draftsman call them "faired" lines. They are produced by drawing a smooth curve through a number of previously established points, using a long plastic spline (strip) held in place with special lead weights.

In the school shop small curves can be laid out with an irregular curve (sometimes called a French curve) which is usually included in the drafting equipment. A large curve can be laid out with a thin strip of wood in about the same way the draftsman uses a spline. It can be clamped to the wood for a single layout or used to develop a pattern.

To develop a pattern, fasten a sheet of paper to a piece of cork board or hardboard. Set large pins or small nails at the points you want the curve to pass through. Thread the wood strip through these points and draw a line along its edge, Fig. 5-2.

PATTERNS AND TEMPLATES

A pattern is a full-size outline of an object drawn on paper. Some patterns can be developed from dimensions given on a drawing. Complicated curves and outlines are included in working drawings but are usually not full size and need to be enlarged. This can

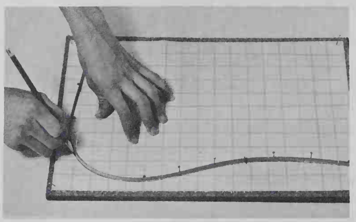


Fig. 5-2. Making a quarter pattern using a thin wood strip.

be easily done by a method called "enlarging with squares." Study the drafting book in this series for a complete description of the method. Basically, it is accomplished by laying out small squares (if not included on the drawing) over the contour to be enlarged. On a sheet of paper lay out larger squares (size depends on the scale or ratio), and number them to correspond with the squares on the drawing. Work with one square at a time and draw a line through the large square in the same way it goes through the corresponding small square.

When a design is the same on both ends, you need only a half pattern. This is laid out on one side of a center line, Fig. 5-3, and then turned over and laid out on the other side. Some designs require only a quarter pattern such as the one being used in Fig. 5-4.

You can transfer a pattern to wood by cutting it out and drawing around the edge or placing a piece of carbon paper between the pattern and the wood

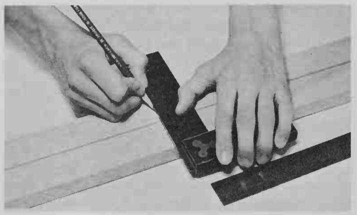


Fig. 5-3. Laying out center lines.

surface and tracing over the lines. Secure the pattern to the work with drafting tape or thumb tacks so it will not slip. When tracing a pattern onto wood, use a straightedge and irregular curve to produce smooth lines on your work.

When you have a number of identical pieces to lay out it is usually best to make a template. Glue your paper pattern (use rubber cement) onto a heavy piece of cardboard or a thin piece of plywood or hardboard. Carefully cut out the design and then smooth the edges by filing and sanding.

CUTTING CURVES

A coping saw and a compass saw are hand tools used to cut curves. The coping saw has fine teeth (usually about 16 points or 15 teeth to the inch) and makes the smoothest cut.

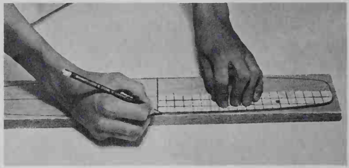


Fig. 5-4. Using a template to lay out a curve.

Coping saw work can be clamped in a vise, or held on a saw bracket or V support as shown in Fig. 5-5. When the work is held in a vise the blade should be mounted in the saw frame with the teeth pointing away from the handle. For work held on the saw bracket the teeth should point downward or toward the saw handle.

Start the cut in the waste stock and then guide the saw to the edge of the cutting line. Use steady, uniform strokes, keeping the blade perpendicular to the surface. Give the saw plenty of time to cut its way. Use extra strokes as you go around sharp corners. Reposition the work as you progress so the cutting will be taking place near the point of the V support or close to the jaws of the vise.

Working slowly (about 50 strokes a minute) and carefully will actually save time because you will not need to do as much filing or sanding to finish the

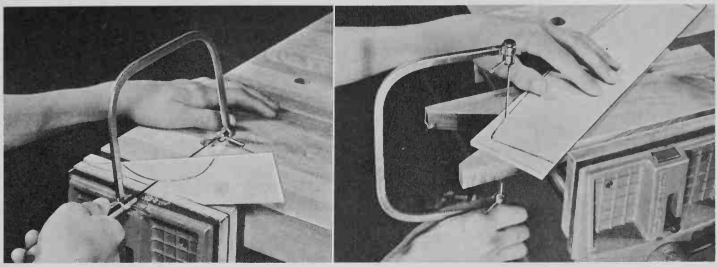


Fig. 5-5. Cutting with a coping saw. Left. Work being held in a vise. Right. Work being held on a V support.

edges. A new blade may "bite" into thin stock too fast for a smooth cut, and usually works better if it is given a few light strokes with a piece of fine sandpaper.

Curves that are formed by removing only a small amount of stock can be cut with a chisel. Inside curves are cut with the bevel held against the work and outside curves with the bevel turned out. Cut with the grain working toward the center of a curve as shown in Fig. 5-6.

SMOOTHING CURVES

The spokeshave is practical for smoothing and shaping a curved edge or surface. It is sharpened and adjusted somewhat like a plane. The spokeshave was originally designed to shape the wooden spokes of wagon wheels.

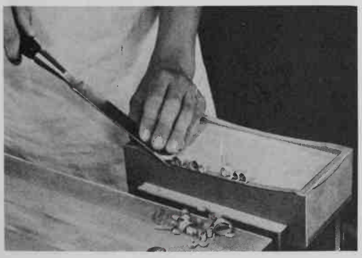


Fig. 5-6. Cutting a curved edge with a chisel.

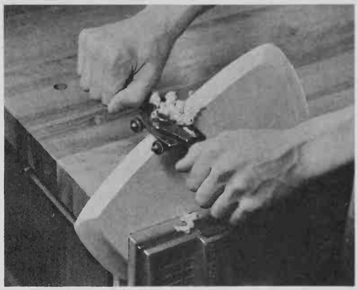


Fig. 5-7. Using a spokeshave.

Adjust the spokeshave and experiment with it on a piece of scrap wood. Mount your work in a vise. Hold the tool in both hands as shown in Fig. 5-7. It can either be pulled toward you or turned around and pushed. Take light cuts and work with the grain. Hold it at an angle with the work when cutting end grain.

For smoothing surfaces that are small or have sharp curves, it is best to use a wood file. The most common files for woodworking are the round, half-round and flat. Small metal files are sometimes helpful in smoothing intricate work. See Fig. 5-8.

When possible, use a stroking action rather than filing straight across an edge. Try to file in from each edge to prevent splitting the opposite side; this is

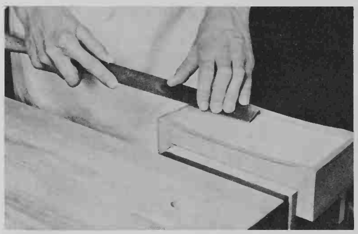


Fig. 5-8. Shaping an edge with a half-round file.

Fig. 5-9. Forming inside of tray with gouge.

especially inportant when working with plywood. Use a file card or file cleaner to keep the file teeth clean. A file should have a tight-fitting handle.

CARVING AND SHAPING

Gouges and chisels of various shapes are used for carving wood. They should be kept in a box or special holder when not being used, to protect the worker and also the cutting edges.

When carving wood, clamp the stock securely, either in a vise or in some special holder. Hold the tool in both hands and make cuts moving away from you. The angle of the tool edges will vary; however, most of them should be held at about a 30 deg. angle. Cut with the grain wherever possible.

Use a large outside-ground gouge to form the inside of a tray or boat hull. Start in the center and gradually enlarge the area. Cut long, thin shavings, with the tool moving toward the center as shown in Fig. 5-9. Guide the blade with your left hand (if you are right handed) and force it through the wood with your right hand. Rolling the cutting edge slightly will help it cut, especially on end grain.

CHAMFERS AND BEVELS

A chamfer removes the sharp corner from an edge and improves the appearance of some work. It is usually made at a 45 deg. angle with the surface or edge of the stock.

Lay out a chamfer with a sharp pencil held so the fingers serve as a guide along the edge of the stock, as shown in Fig. 5-10. A marking gage cannot be used, since it will leave a groove.

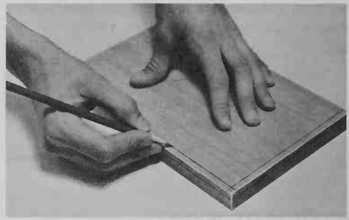


Fig. 5-10. Laying out a chamfer.

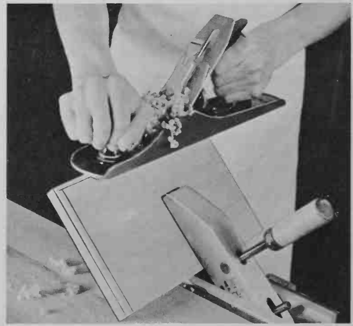
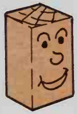


Fig. 5-11. Planing a chamfer.

Clamp the stock in a hand screw and clamp the hand screw in a vise, so the work will be held at an angle. Plane the edges first, and then plane the ends with the plane held at an angle to make a shearing cut. See Fig. 5-11.

A bevel is a sloping edge that connects the two surfaces of the stock. It is laid out and cut in about the same manner as a chamfer. A sliding T-bevel should be set at the required angle and used to check the work.



WOODY SAYS:

"When using a chisel always keep both hands back of the cutting edge with cutting motion away from you."

TAPERS

A taper runs along the length of stock causing it to be smaller at one end than the other. The legs of stools, chairs, and tables are often tapered.

First, square the stock to be tapered to its largest dimension. Lay out the length of the section to be tapered, mark the size of the small end and draw a line on each edge. Clamp the work in a vise and plane toward the tapered end.

For legs that are tapered on all four sides, first lay out and plane the taper on two opposite faces, as shown in Fig. 5-12. Mark the taper on these surfaces,

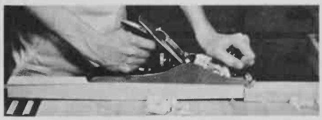
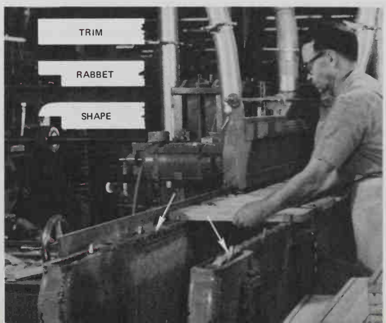


Fig. 5-12. Planing a taper.

and plane the remaining two sides. Tapers are hard to clamp in a vise and you may need to work out some special clamping arrangement.

QUIZ – UNIT 5

1. Before laying out and cutting curved pieces from solid stock, the surface of the stock should be ________ .
2. To lay out a large circle, use a set of ________ ________ or use a pencil and string.
3. When a full-sized outline of an object is drawn on paper it is called a ________ .
4. If your project contains a number of curved pieces that are the same size and shape, you should use a ________ to lay them out.
5. A standard coping saw blade has ________ points to the inch.
6. A tool that was originally designated to form wooden wheel spokes is called a ________ .
7. Three common shapes of wood files are flat, round and ________ .
8. Most chamfers are made at a ________ deg. angle with the surface or edge of the stock.
9. When planing a chamfer the work should be clamped so the plane can be held in a ________ position.
10. When planing a taper the cut should usually be made toward the ________ end.



Modern double-end tenoner. Feed chains (arrows) carry workpieces through saws and cutterheads – located on both sides. In the setup shown, drawer front blanks are first trimmed to exact length, rabbets are cut, and then the ends are shaped (see insert drawing). A special sanding attachment smooths the shaped surface as the pieces leave the machine. (Norton Co.)

Unit 6

DRILLING AND BORING HOLES

After studying this unit, you will know:
1. **How to lay out hole positions.**
2. **How to use a brace and bit to bore holes.**
3. **How to bore holes at an angle.**
4. **How to use a hand drill.**

Cutting small holes (1/4 in. dia. or less) in wood is called drilling. This operation is usually performed with a twist drill or drill press. Boring is the term used for cutting larger holes with the brace and auger bit or with a brad point bit mounted in a drill press.

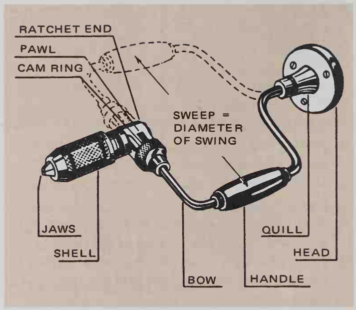


Fig. 6-1. Parts of a brace. (Stanley Tools)

BRACES AND AUGER BITS

The size of a brace is determined by its "sweep," Fig. 6-1. Braces are available in sizes 8 to 14 in. A good size brace for a school shop is either 8 or 10 in. Most braces are equipped with a ratchet that permits boring in a corner even though a complete revolution of the handle cannot be made.

The most common types of wood bits are the double twist shown in Fig. 6-2, and the solid center. Fig. 6-5. A single twist is often used for boring deep holes because chips seldom clog in the spiral. There

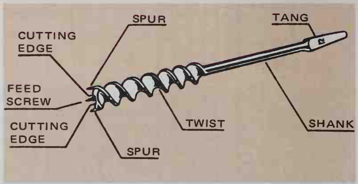


Fig. 6-2. Parts of an auger bit.

are other types of boring tools especially designed for use on power equipment.

Auger bits are available in sizes ranging from a No. 3 through No. 32. This number is stamped on the tang of the bit and indicates the size in sixteenths of an inch. For example, a No. 5 would be 5/16 in. in diameter; a No. 12 would be 12/16 in. or 3/4 in. in diameter. A standard auger bit set is made up of numbers 4 through 16.

SHARPENING AN AUGER BIT

Sharpening an auger bit requires considerable skill and careful work. You should check with your instructor before attempting this operation.

A special auger bit file should be used to sharpen auger bits. Sharpen the cutters first by stroking upward through the throat as shown in Fig. 6-3. Use medium pressure and stop as soon as the edge is sharp. Try to maintain the original bevel. Turn the bit over and file the spurs on the inside surface only. Keep the bit balanced by filing the same amount on both sides.

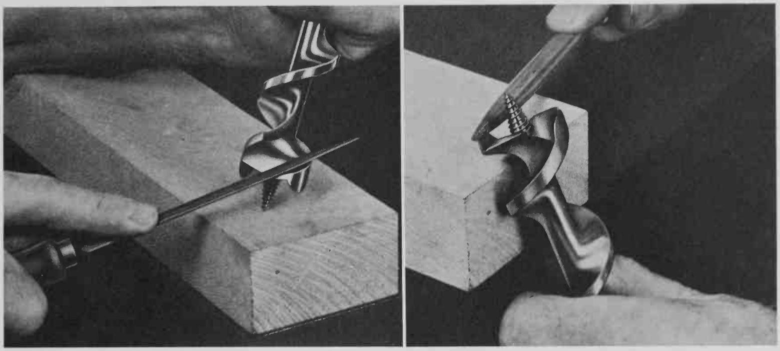


Fig. 6-3. Sharpening an auger bit.
(Greenlee Tool Co.)

The edges on an auger bit will stay sharp a long time if the bit is carefully handled. When not in use, keep auger bits in special holders, or in boxes or cloth rolls in which they were packed by manufacturer.

BORING A HOLE

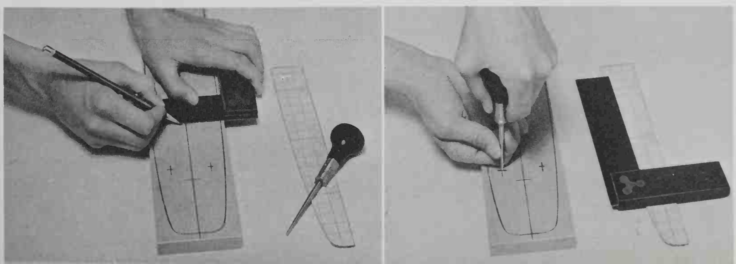
Measure and lay out the position of the hole by drawing center lines on the best face of the stock. Punch a small hole with a sharp scratch awl where these lines intersect. Fig. 6-4.

The stock may be fastened in the vise in either a horizontal or a vertical position. It should be firmly clamped to a piece of waste stock that will support the wood around the edges of the hole when the bit cuts through the opposite side. When boring a large hole in a small piece of wood, prevent splitting by applying pressure to the sides with a hand screw.

Select the correct size bit and insert it well into the jaws of the brace. The corners of the tang are held in the Vs of the jaws. You can tighten or loosen the jaws by holding the shell and turning the brace handle.

Guide the bit with your left hand and set it in the hole marked with the awl. Turn the brace clockwise. Keep the bit perpendicular to the surface of the wood. Have another student help you "sight" this angle, or keep the bit aligned with a try square as shown in Fig. 6-5.

Fig. 6-4. Laying out center lines and center punching holes with a scratch awl.



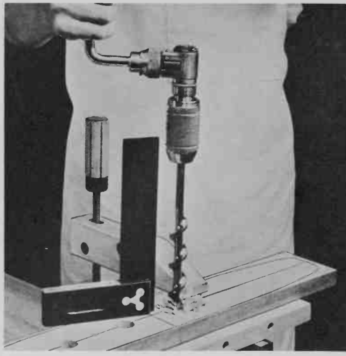


Fig. 6-5. Boring hole with brace and bit in vertical position. Notice the work is clamped to a piece of scrap wood.

It is usually easier to keep a bit perpendicular to the work when boring in a vertical position, but on some jobs it may be difficult to exert enough pressure. When an auger bit does not feed into the work properly, check the threads of the feed screw and see that they are clean.

Use extra care when starting a hole in plywood or you will splinter the veneer around the edge of the hole. Start the feed screw and turn the bit until the spurs just begin to score the outside of the hole. Turn the bit about a half turn backward, then forward, several times, until the surface veneer is completely cut, before continuing to bore the hole.

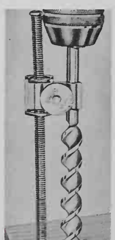


Fig. 6-6. A spring-type bit depth gage.

If it is not convenient to "back up" the stock with scrap wood, you can bore from one side until the feed screw just starts to come through, then reverse the stock and finish the hole from the other side.

Hole depth may be regulated by using a depth gage, as shown in Fig. 6-6. An example of boring a hole with the brace and bit in a horizontal position is shown in Fig. 6-7.

COUNTERBORING

Sometimes it is necessary to have a hole of two different diameters. If you want to place a screw head below the surface of the work, you should first bore a hole for the head to the required depth and then make a hole with a drill that matches the size of the shank of the screw. It is important that you bore the holes in this order. If the small hole is bored first there will be no way to center the larger bit.

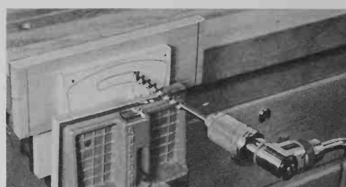


Fig. 6-7. Boring a hole with the brace and bit in a horizontal position.

BORING HOLES AT AN ANGLE

To bore a hole at an angle, set a sliding T-bevel at the required angle (use a protractor or the miter gage of the table saw) and place it on the surface to be bored. Start the feed screw and then tilt the bit to align with the blade of the T-bevel.

If you have several holes to bore at the same angle you can do more accurate work if you make a "boring jig" as shown in Fig. 6-8. It may be necessary for you to bore several holes before you get the angle you want. Place the jig on the bit and position the feed screw in the center punched hole. Start the feed

screw by turning it about one turn. Tilt the bit and clamp the jig to the surface of the work. A piece of drafting or masking tape can be placed around the bit to serve as a depth gage.

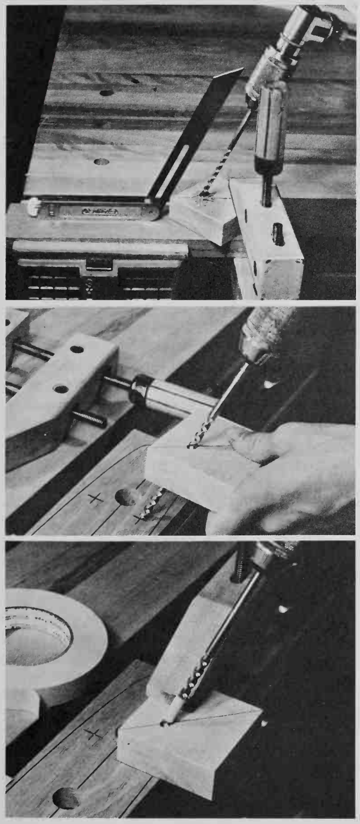


Fig. 6-8. Making and using a jig to bore holes at an angle. Above. Boring the jig. Center. The bit has been "threaded" through the jig and is being placed in the punched hole. Below. The jig has been clamped to the stock and the hole is being bored.

USING AN EXPANSIVE BIT

An expansive bit has adjustable cutters (usually two cutters) and will bore various size holes, Fig. 6-9.

Adjust the cutter so the distance from the spur to the center of the feed screw is equal to the radius of the hole. Some bits have a scale that will help you make this setting. After making the setting, lock the cutter securely. Start a test hole in a scrap block and measure it to check the setting before using it on your project.

It is better to bore through waste stock than to reverse the piece and finish the hole from the opposite side.

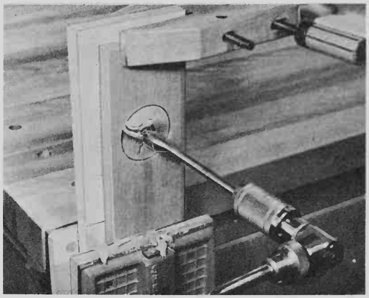


Fig. 6-9. Boring with an expansive bit.

USING A FORSTNER BIT

A Forstner bit does not have a feed screw and is used for boring holes that go only part way through the stock and require a smooth flat bottom. It can be used to enlarge holes or bore holes in thin stock where the feed screw of a regular bit might cause the stock to split. See Fig. 6-10. Locate position of holes to be bored with Forstner bit by drawing a circle or square the size of bit.

DRILLING HOLES

Holes 1/4 in. and smaller are usually drilled with a hand drill, using straight shanked twist drills. A push

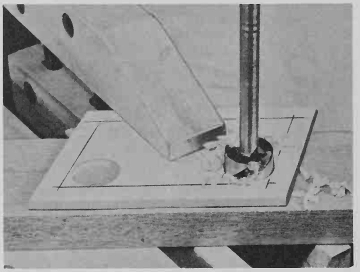


Fig. 6-10. Boring with a Forstner bit.

Fig. 6-12. Drilling a hole with a hand drill.

drill that required a special type of bit can be used for holes 1/16 in. to about 3/16 in. See Fig. 6-11. Carpenters quite often use a push drill to make holes for nails and screws. Such a drill can be operated with one hand.

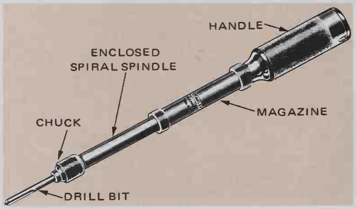


Fig. 6-11. Parts of push drill.

The size of a hand drill is determined by the capacity of its chuck (largest drill it will hold). The most common size for the school shop is 1/4 in. Twist drills are available in a wide range of sizes. For woodworking a good set should range from 1/16 to 1/4 in. by thirty-seconds.

In drilling holes, use the same procedure as suggested for boring holes. It is important that the hole be started with an awl since the twist drill has a blunt point. Place a twist drill all the way in the drill chuck. The jaws of the chuck may be opened and closed by holding the chuck and turning the handle.

Hold the handle in your left hand and keep the drill perpendicular to the wood surface, while turning the crank with your right hand. Small drills will break if you do not work carefully. Since there is no feed screw on a drill bit, you will control the feed by the pressure you apply. The amount of pressure to apply varies with the size of bit and the kind of wood. Drill to the required depth and continue to turn the drill while pulling it out of the hole. If the hole is deep, pull the drill out several times to clear the cuttings. Remove drill from chuck as soon as you have finished using it. See Fig. 6-12.

QUIZ – UNIT 6

1. The size of a brace is determined by the diameter of the handle swing or ________.
2. The two most common types of auger bits are the double twist and the ________ ________.
3. The number size of an auger bit is stamped on the ________.
4. To bore a 3/8 in. hole, you should select a No. ________ auger bit.
5. A No. 8 auger bit will bore a hole that is ________ in. in diameter.
6. When sharpening an auger bit the spurs should be filed on the ________ surface.
7. Before boring a hole with the auger bit the center should be punched with a ________ ________.

Unit 7
CLAMPING AND GLUING WOOD

After studying this unit, you will know:
1. **Which kinds of glue are used for woodwork.**
2. **How to make glue "spreads."**
3. **How to use wood clamps.**

WOOD GLUES

Research and developments in the last decade have produced many new adhesive products. The field of adhesives has become highly technical and complicated. We shall confine our study here to just a few adhesives that are most satisfactory for your work in the school shop.

POLYVINYL RESIN EMULSION GLUE (often referred to as white glue or just polyvinyl) has received wide acceptance. It comes ready for use in plastic squeeze bottles and is easily applied. This glue sets up rapidly, does not stain the wood or dull tools, and it holds wood parts securely.

Polyvinyl glue hardens when its moisture content is removed through absorption into the wood or through evaporation. Its "setting time" therefore depends somewhat on the porosity of the wood. It is not waterproof and should not be used in assemblies that will be subjected to high humidity or water. Polyvinyl does not resist high temperature (160F and higher) and should not be used in the construction of such articles as radio or TV cabinets. It never gets "brittle" hard and this characteristic makes it difficult to sand from a wood surface.

UREA-FORMALDEHYDE RESIN GLUE (usually referred to as urea resin) comes in a dry powder form. It is mixed with water to a creamy consistency for use. It is moisture-resistant, stains the wood only slightly and dries to a light brown color. It holds wood surfaces securely.

Urea resin hardens through chemical action in somewhat the same manner as portland cement. Elevated temperatures accelerate this action so if you want to speed up the setting of your glue joints you may do so by placing them on a radiator or under a heat lamp. Wood is not a good conductor of heat; therefore, if the pieces are large it will take some time for the heat to penetrate to the "glue line."

This glue is well suited for use when gluing cutting boards, salad bowls, and articles that may be subjected to moisture for a short period of time.

RESORCINOL RESIN GLUE comes to the woodworker in two components; (1) a dark reddish liquid resin, and (2) a powdered or liquid hardener (sometimes called a catalyst). The components are mixed together for use. This glue has a "working life" of from two to four hours. Resorcinol glue has about the same working characteristics as urea resin. Its great advantage lies in its waterproof feature. It can be used with good results on boats, water skis or other structures exposed for long periods to high humidities or water.

TRY IT DRY — FIRST

Before applying any kind of glue you should place the parts together (trial assembly) and adjust the necessary clamps. Check the fit and squareness. All surfaces, especially inside ones, should be sanded before the final glue-up.

The wood surfaces that form the "glue line" should be dry, clean and free of sand dust and should make smooth contact with each other.

The joints should fit together without excessive pressure from clamps. If you force an assembly together you will be gluing stresses into your project that may eventually cause the joints or structural members to fail.

When using bar clamps on surfaces that are ready for finishing, it is important to use wood blocks under the clamp jaws to protect these surfaces from dents and stains.

MIXING POWDERED GLUES

Fig. 7-1 shows the mixing of urea resin glue. Since this glue has a working life of only two to three hours, you should mix just the amount needed for each job. A paper cup makes a good mixing container since it can be discarded when the job is finished.

Pour the dry powder into the cup and add a small amount of water. Stir with a stiff brush or stick until it forms a heavy "gooey" mass, then add a few drops of water at a time until you have reduced it to a smooth creamy consistency. Manufacturers of urea resin glue usually recommend a proportion (by measure) of eight parts of powder to three parts of water.

Be sure to close the container of powdered resin tightly, otherwise it will gather moisture from the air and harden in the container. If you use a brush to apply the glue it can be washed with warm water and soap.

Resorcinol glue should be handled in about the same manner as urea resin. Be sure to read the manufacturer's directions on the label. It is best to use sticks for mixing and application, since this type of glue is very difficult to remove from a brush.

MAKING THE GLUE SPREAD

Applying the glue to the wood surface is called "spreading." When the glue is applied to both wood surfaces to be joined it is called a "double spread" and when it is applied to only one surface it is called a "single spread."

Woodworking industries often use only a "single spread" since they have various devices and gluing machines that carefully control the amount of glue applied. For your work in the school shop it will be best to make a double spread (apply a coat of glue to both mating surfaces).

You must use good judgement as to how heavy to make the spread. The surface should be thoroughly coated, yet not so heavy that you will have excessive "squeeze-out" for this will make the work messy and be wasteful of glue.

Fig. 7-1. Mixing powdered glue.

The time interval between coating the surfaces and bringing them together will vary with the type of glue used. When using polyvinyl you should close the assembly within two minutes. You will have about four minutes of "open assembly" time with urea resin at regular room temperatures and a much longer period with resorcinal resin.

Fig. 7-2 shows a sequence of gluing steps when working with polyvinyl. Notice that the double spread is made by rubbing the two pieces together. Where this spreading method is not practical, a stiff glue brush may be used. The brush should be cleaned in warm water immediately after use.

When spreading glue on a miter or butt joint the end grain of the wood will absorb extra glue. You can insure a good joint by making a second spread over these surfaces after the first spread has a few moments to soak in.

Since the "open assembly" time for polyvinyl is so short, you should plan to glue only a few parts of a complicated assembly at a time. This will not slow you down too much, since the glue sets rapidly.

CLEANING THE JOINT

On final assemblies, where the project surfaces have been sanded and are ready for finishing, it is important to keep them free of glue. Even the slightest amount of glue will seal the surface and cause a blemish in the final finished surface. Glue

should be applied carefully so there is a minimum of "squeeze-out." That which does appear around the joint should be removed immediately and the surface "washed" with a sponge or rag rung out in hot water, Fig. 7-4.

Complete removal of the "squeeze-out" is not necessary when making edge or face joints. These joints are used to build wider or thicker stock and the excess glue is removed when it is worked to its

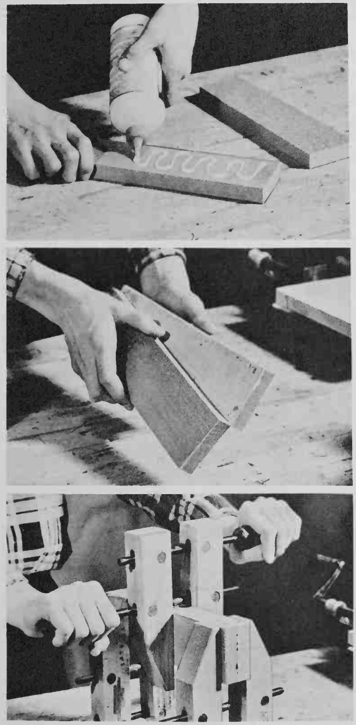


Fig. 7-2. Gluing sequence using polyvinyl glue. Above. Applying from a "squeeze" bottle. Center. Making a "double spread." Below. Clamping with handscrew.

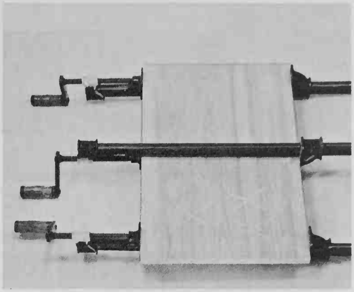


Fig. 7-3. Bar clamps holding edge joints.

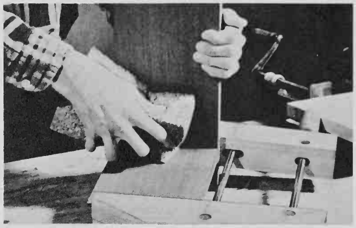


Fig. 7-4. Removing glue from the surface of the wood with a damp sponge.

finished dimension, Fig. 7-3. A wood scraper should be used to remove glue after it has hardened.

SETTING TIME

The setting time varies with the temperature of the glue line, the kind of wood, and the type of glue.

Polyvinyl takes an initial set in from 15 to 20 minutes. Most assemblies can be removed from the clamps after this period. Several hours, however, are required before it gains its full strength. Steel bar clamps that contact the glue line should not remain overnight as this will cause a stain in the wood.

Urea resin sets up more slowly. Projects should be left in clamps for several hours at room temperature.

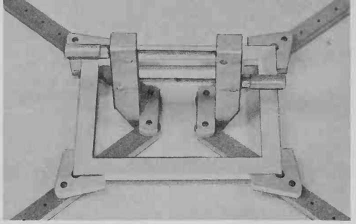


Fig. 7-5. This jig makes it easy to assemble miter joints.

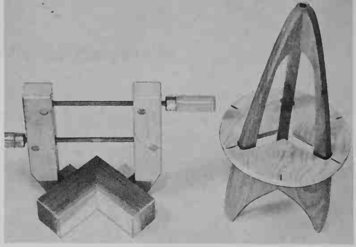


Fig. 7-6. Special clamping methods. Left. Small blocks are glued in place and then split off after the miter joint has been glued. Right. The plywood "yoke" for a tripod lamp applies pressure and holds the legs in proper position.

Either of these glues should cure over night before continuing to work with the material. This is especially true of polyvinyl as it gives the moisture absorbed from the glue line time to disperse through the wood and evaporate.

SIZES OF WOOD CLAMPS

Bar clamps, the type of clamps shown in Fig. 7-3, vary in size from two to eight feet. This size applies to the largest actual opening obtainable between the jaws.

The handscrews shown in Fig. 7-2 are sized by numbers ranging from 5/0 to 7. The 5/0 is the smallest and has a jaw 4 in. long. The next size is a 4/0 and has a 5 in. jaw. The largest size (Number 7) has a jaw length of 24 in.

Some of your assemblies may not be adaptable to regular wood clamps, and you will need to design special holders or jigs. This is comparable to work in industry. When new parts are designed, it is usually necessary to develop special tools, jigs and fixtures to provide speed and accuracy. Note Figs. 7-5, 7-6.

QUIZ – UNIT 7

1. Polyvinyl resin glue is a type of glue that hardens when its ________ content is removed.
2. The greatest disadvantage of polyvinyl resin glue is that it is not ________ .
3. Urea resin glue must be mixed with ________ before it is used.
4. Urea resin hardens due to chemical action and becomes a light ________ color.
5. It is possible to speed up the setting time of urea resin glue by raising the ________ of the glue line.
6. A glue designed for wood that is classified as being completely waterproof is called ________ resin.
7. Some resin glues are designed to set up when a catalyst or ________ is added to them.
8. When the parts of a project are fitted together before applying glue it is called a ________ ________ .
9. When using bar clamps to hold an assembly you should protect surfaces that are ready for finish by using ________ .
10. When glue is applied to both of the wood surfaces being joined it is called a ________ ________.
11. The open assembly time when working with polyvinyl glue should not be over ________ minutes.
12. The open assembly time for urea resin is ________ minutes.
13. A second spread of glue should be made on the end grain of butt and ________ joints.
14. Urea resin glue is usually mixed to proportion (by measure) of 8 to ________ .
15. Excess glue that has hardened on edge joints should be removed with the ________ .
16. In addition to the type of glue and temperature of the glue line the setting time will vary somewhat depending on the kind of ________ .
17. Joints glued with polyvinyl can usually be removed from the clamps in about ________ minutes.
18. When gluing up stock for cutting boards the most practical glue to use is ________ ________.
19. Standard bar clamps vary in size from two to ________ feet.
20. The number size of handscrews is determined by the length of the ________ .

Unit 8

METAL FASTENERS FOR WOODWORK

After studying this unit, you will know:
1. How to drive nails.
2. What kinds and sizes of nails are used.
3. How to use wood screws to assemble wood parts.

HAMMERS AND NAILS

You probably have already had some experience driving nails. Nevertheless you should check Fig. 8-1 to be sure that you know the correct procedure. Notice where the hand grips the hammer. Center lines through the nail and hammer handle should form a right angle when the hammer face strikes the head of the nail.

Start the nail with light strokes, then get the hand that held the nail well out of the way. Use a fairly full swing (depending on the size of the nail) to get power in the stroke. Keep your eyes on the nail head — just like you would do when hitting a baseball or golf ball. Ease up on the power of your stroke when the head gets close to the surface of the wood, and stop when the head is flush. Do not "batter-up" the surface of the wood. Hammer marks are the trade marks of an ameteur.

Brads, finishing nails and casing nails are used on finished woodwork. A nail set should be used to bring the nail head flush with the surface, or just under the surface.

Nails are easy to drive in soft wood but are real "tricky" to handle in hard wood. A thin film of paste wax or soap on the nail will insure better results. Be sure to keep the face of the hammer clean and shiny. For very hard woods it is best to drill a pilot hole.

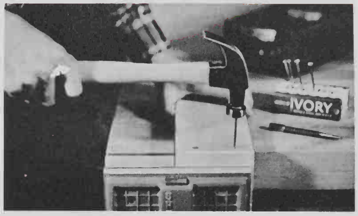


Fig. 8-1. Driving a nail.

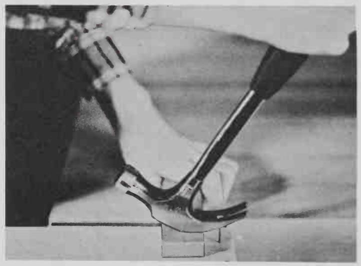


Fig. 8-2. Pulling a nail. Notice wood block placed under hammer to increase leverage and protect the wood surface.

KINDS AND SIZES

The quality of your nailing job will depend a lot on your judgment when selecting the correct size of hammer and nails.

Claw hammers are the standard tools for driving nails. They range in size from 7 oz. to 20 oz. (this is the weight of the head). The most common sizes for the school shop are 10 oz. and 13 oz. Fig. 8-2 shows a 13 oz. hammer being used to draw or pull a nail.

There are many kinds and sizes of nails. Those shown in Fig. 8-3 are standard types that you should be able to readily identify. The common nail has a heavy cross-section and is used for rough carpentry work. The lighter box nail is used for light construction, crating and boxes. The casing nail is the same weight as the box nail, but has a small conical head. As the name implies it is used in finished carpentry work to attach door and window casings and other interior woodworking trim. Finishing nails and brads are quite similar, and have the thinnest cross-section and the smallest head.

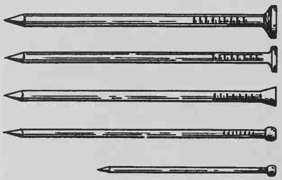


Fig. 8-3. Types of nails.

The nail size is called a "penny," which is abbreviated with the lower case letter d. It indicates the length of the nail. A 2d (2 penny) nail is 1 in. long and increases 1/4 in. for each penny. For example, we could determine the length of a 4d nail by the following: 1 + (2 x 1/4) = 1 1/2 in. long. An 8d nail would be 2 1/2 in. long. This measurement applies to common, box, casing and finishing nails. Brads are specified by stating their actual length and wire gage number.

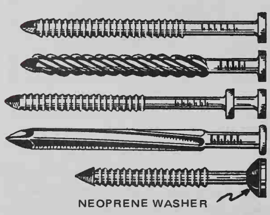


Fig. 8-4. Nails for special purposes.

Fig. 8-4 shows a few of the many specialized nails available today. Each is designed for a special purpose. These nails are made of such materials as iron, steel, copper, bronze, aluminum and stainless steel. Some nails have special coatings of zinc, cement or resin. Coating or threading a nail will increase its holding power three to four times that of a smooth nail.

WOOD SCREWS

Wood screws provide greater holding power than nails and make disassembly of parts easy. However, they require more time to install and are used chiefly in high grade cabinetwork and furniture construction.

The size of wood screws is determined by their length and diameter (gage number). They are classified according to the shape of head (Fig. 8-5), surface finish, and the material from which they are made.

Wood screws are available in lengths from 1/4 to 6 in. and in gage numbers from 0 to 24. The gage number can vary in any given length of screw. For example, you could select a 1 1/2 in. screw with a No. 7 gage, or the same length in a No. 14. The first would be a thin screw, while the second would have a much larger diameter. From one gage number to the next, a wood screw varies by .013 in. (13 thousandths). An average diameter 1 1/2 in. screw would have a gage number of about 10.

Most wood screws are made of mild steel with no special surface finish. They are concealed in the cabinet or furniture structure. Such screws are labeled as F.H.B., which stands for flat head bright. When the screws are to be visible, they should be nickel or chromium plated, or made of brass with an oval or round head.

To completely specify wood screws you should describe them in detail; for example:

10 – 1 1/4 x No. 8 – Round Head – Nickled.

To secure the maximum holding power, select a screw long enough to enter the base piece of wood the entire length of the screw threads. This will be about two thirds of the screw length. Thin stock may not permit this length. You will need to apply good judgment in your selection. The "end grain" of wood does not hold screws well, an extra long screw should be used.

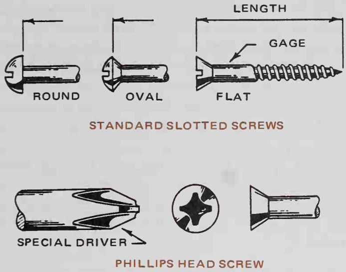
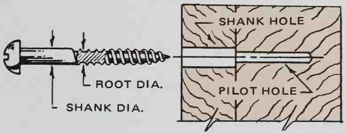


Fig. 8-5. Types of wood screw heads.



SCREW GAGE	5	6	7	8	9	10	12
SHANK HOLE	1/8	5/32	5/32	3/16	3/16	3/16	7/32
PILOT HOLE	1/16	3/32	3/32	3/32	1/8	1/8	5/32

Fig. 8-6. Approximate drill size to use for some common screw gages.

DRILLING HOLES FOR WOOD SCREWS

To fasten wood together with screws, two different size holes should be drilled for each screw. One should be the size of the screw shank, and the second the size or the root diameter of the screw thread, as shown in Fig. 8-6.

Use good judgment in selecting the size of the drill bits. The size of the shank hole should be just large enough so that the screw can be pushed in with the fingers. The size of the pilot hole (sometimes called the anchor hole) for a given screw will vary depending on the hardness of the wood. For example, white pine may not need a pilot hole while with oak or hard maple a pilot hole is essential and must be carefully sized. Pilot holes for very small screws can be made with a brad awl.

Flat and oval-head screws should be countersunk. Use a countersink in a bit brace, and cut just deep enough to fit the underside of the head exactly. Fig. 8-7. Flat-head screws look especially bad if not aligned perfectly with the wood surface.

SCREWDRIVERS

Before you attempt to drive wood screws, be sure the tip of the screwdriver looks like those shown in Fig. 8-8. The tip must be square, the correct width, and fit squarely into the screw slot. To recondition the tip it should be carefully shaped on a grinder, and the ground surfaces honed on an oilstone.

The size of a screwdriver is specified by the length of its blade, measuring from the handle to the tip. They range in size from 1 1/2 to 18 in. The most common sizes for woodworking range from 2 1/2 to 6 in.

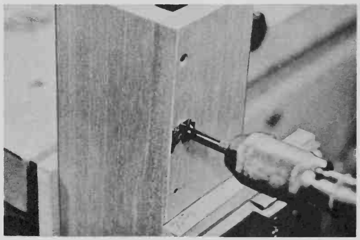


Fig. 8-7. Countersinking for a flat-head screw.

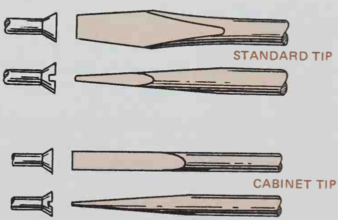


Fig. 8-8. Screwdriver tips.

If you have drilled holes for the screw properly, it's an easy matter to insert the screw in the shank hole and drive it "home" with the screwdriver, Fig. 8-9. Use care that the screwdriver does not slip out of the slot and dent the surface of your work. Using Phillips type screws helps eliminate this problem because the tip cannot easily slip out of the screw slot. A screwdriver bit mounted in a brace or an automatic screwdriver, will save time when you have a large number of screws to set.

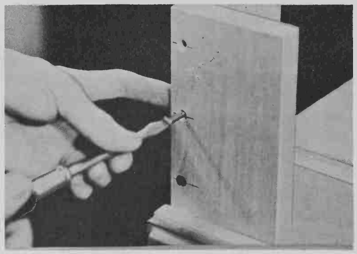


Fig. 8-9. Driving a 1 3/4 in. No. 9 – F.H.B. screw with a 4 in. screwdriver.

As in the case of nails, soap or wax will allow the screw to be driven easier into hard woods. Do not apply too much force as you may twist the screw off. Screws usually break just where the threads start, and are very difficult to remove. Too much force, or a poor screwdriver tip, will damage the slot in the screw head and make your work appear shoddy.

Brass screws are very soft and must be given special care. Sometimes it is worthwhile to first drive a steel screw of the same size (this will cut threads in the pilot hole), then remove and insert the brass screw.

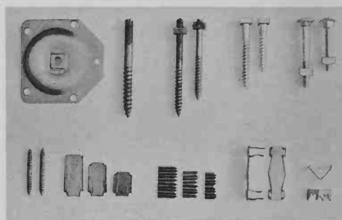


Fig. 8-10. Some special fasteners. Top row – mounting plate, hanger bolts, lag screws, carriage bolts. Bottom row – dowel screws, splines, corrugated fasteners, wood joiners and chevrons.

QUIZ – UNIT 8

1. When driving a nail you must keep your eye on the __________ head.
2. A tool that should be used with the hammer when driving a nail below the surface of the wood is called a __________.
3. Claw hammers range in size from 7 oz. to __________ oz.
4. The largest size of claw hammer recommended for woodwork in the school shop is a __________ oz.
5. The size of a hammer is based on the weight of its __________.
6. The type of nail most often used in crating and rough boxes is the __________.
7. Size of nails is designated by word "penny" and is abbreviated with case letter __________.
8. The length of a 6 penny nail is __________ in.
9. Brad size should be specified by its length and __________ number.
10. When nailing a 1 x 4 to a face of a 2 x 4, the largest size of nail you can use and not have it go through the 2 x 4 is a __________.
11. The size of wood screws is determined by their shank gage and __________.
12. Wood screw gages vary from 0 to __________.
13. The next size smaller shank gage of a No. 10 screw would be a No. __________.
14. The difference in diameter between a No. 12 and No. 14 wood screw would be __________ thousandths of an inch.
15. The wood screw most often used for general construction is labeled with the letters __________.
16. When setting screws in hard wood it is always best to drill a pilot hole and a __________ hole.
17. The size of a screwdriver is determined by the length of its __________.

Unit 9

SANDING AND PREPARING FOR FINISH

After studying this unit, you will know:

1. **What kinds and grade of abrasive papers are used for woodwork.**
2. **How to use abrasive paper for smoothing wood surfaces.**
3. **How to sharpen and use a wood scraper.**
4. **How to patch defects in wood surfaces.**

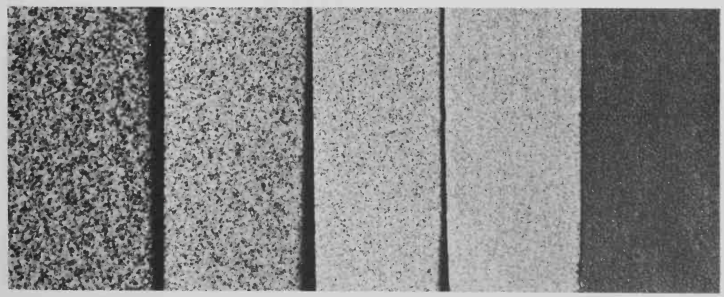
Sanding is the process of cutting the wood fibers with an abrasive (a hard material that grinds and wears away a softer material). The chief purpose of sanding is to smooth the wood surfaces and prepare them for finishing coats. It is a very important operation because clear finishes tend to magnify defects. Scratches and other imperfections that are almost invisible on the dry wood surface are very noticeable when the finish is applied.

Sanding operations should usually not be started until all edge tool work is complete. There will be times when some shaping of the wood can be accomplished best with abrasive paper (commonly called sandpaper). However, you should never try to make abrasive paper take the place of a plane, chisel or other tool.

KINDS AND GRADES OF ABRASIVE PAPER

Abrasive paper is available in flint, garnet, aluminum oxide and silicon carbide types. Flint, garnet and aluminum oxide are common abrasives used in woodwork. Flint and garnet are natural (mined or quarried) materials, while aluminum oxide and silicon carbide are manufactured. Flint is grayish white in color, inexpensive, and used for rough work. Garnet has a reddish brown color and is a good material for hand sanding. Aluminum oxide is a brown material that appears more tan in color on finer grades of paper. It is hard and tough, and is an excellent abrasive for sanding wood. Aluminum oxide is more expensive than the natural abrasives but will cut faster and wear longer. See Fig. 9-1.

Fig. 9-1. Grades of abrasive paper (enlarged).



50 (1/0) 100 (2/0) 150 (4/0) 220(6/0) WET-OR-DRY 320—600

The grade of an abrasive depends on the size of the grits (particles). The original method of grading used a number system, referred to as the "aught." A newer method is the mesh system and indicates the number of openings per linear inch of the silk mesh through which the abrasive grits are screened. Listings of abrasive paper grades usually include both the aught number and the mesh number. A wide range of abrasive grades are available. The ones commonly used for woodwork in the school shop are listed below:

	*AUGHT SYSTEM	MESH SYSTEM
Fine	6/0	220
	5/0	180
	4/0	150
Medium	3/0	120
	2/0	100
	1/0	80
Coarse	1/2	60
	1	50

*Gradually being discarded.

These grades apply to garnet and aluminum oxide. Flint paper is usually listed as very fine, fine, medium, coarse and very coarse.

Abrasive papers are packaged in lots of 50 and 100 sheets, called "sleeves." Ten sleeves are called a "unit." The standard sheet size is 9 in. by 11 in. Flint paper is sold in sheets 9 in. by 10 in.

The grade of abrasive paper you select will make considerable difference in the speed and quality of your work. A carefully planed surface can be sanded with a No. 150 paper and be ready for finish. If light tool marks show on the surface, it will probably be best to start with a No. 100, then finish with a No. 150. When changing from a coarse grade to a finer grade, do not move more than two grade numbers. For example, it would take a great deal of sanding with a No. 180 paper to remove the heavy scratches left by a No. 80 paper. Coarse grades of paper are used for such operations as shaping edges or removing gouge marks.

USING ABRASIVE PAPER

As a general rule, each individual piece should be sanded before assembly. Even when all the pieces are sanded before assembly, a "touch-up" sanding is needed after assembly.

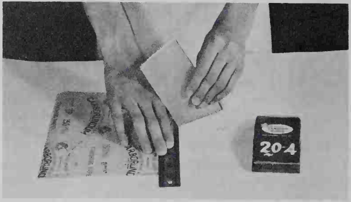


Fig. 9-2. Tearing a strip of abrasive paper along the edge of a steel bench rule.

Sanding should be done in the direction of the wood grain. Abrasive paper will cut faster across the grain. If you have a heavy defect to remove, you may want to resort to this method, but remember you will need to do a great amount of sanding with the grain to remove the "cross grain" scratches.

A full abrasive paper sheet will be too large for your work and will need to be divided into several small pieces. Lay the sheet, grit side down, on a flat surface and tear it along a bench rule or other straight edge, as shown in Fig. 9-2. Coarse grades of paper may need to be folded and creased before tearing.

When sanding flat surfaces, the paper should be mounted or held on a block. The paper will last longer and do better work if the block has a rubber or

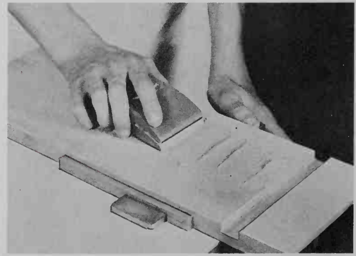


Fig. 9-3. Sanding a wood surface.

felt cushion. The rubber sanding block shown in Fig. 9-3 holds one fourth of a standard sheet.

Before starting to sand a surface, remove pencil marks with a rubber eraser or a scraper. Keep your hands clean during sanding operations and when you handle the work after sanding.

It takes both pressure and motion to make abrasive paper cut. You can apply these best when the wood is held in a vise or clamped to a bench top. Protect sanded surfaces and edges with smooth blocks of scrap wood. Use full strokes and move uniformly over the whole surface. Sand just enough to produce a smooth surface. Excessive sanding on some woods, especially fir, will undercut the soft grain and produce a "wavy" surface. Thin veneers of hardwood plywood must be sanded lightly and carefully.

A sanding block should be used when sanding all edges, chamfers and bevels. Keep the block from rocking so these surfaces will stay flat and not become rounded. Cut out special blocks to fit concave curves and irregular shapes, Fig. 9-4. Some shapes can be sanded with the paper wrapped around a wood file.

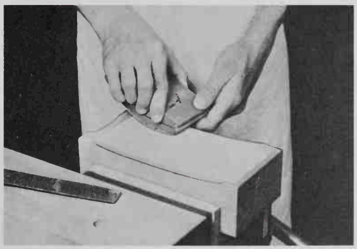


Fig. 9-4. Sanding a curved edge. The abrasive paper has been mounted on the curved side of the rubber sanding block.

SANDING SMALL PIECES

When wood parts are small it is often easier to clamp or hold the abrasive paper against a flat surface and move the wood over it. Fig. 9-5 shows such a procedure using a "sanding board." The board holds a full sheet of paper that is attached with rubber cement. A cleat along the underside is clamped in the vise to hold the board in position. Note Fig. 9-6.

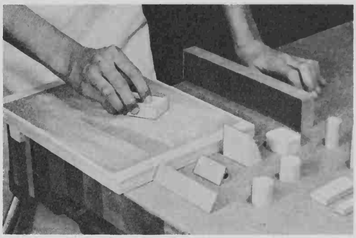


Fig. 9-5. Sanding small parts on sanding board.

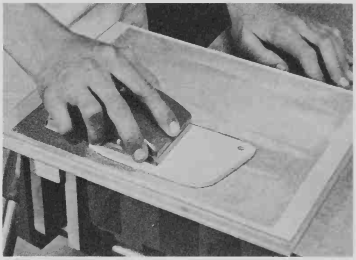


Fig. 9-6. Sanding a small part. Coarse paper on sanding board "holds" the wood piece while it is being sanded with fine paper on the sanding block.

USING A WOOD SCRAPER

If a wood surface has splintered areas because of curly or irregular grain, or ridges left by the plane, it can be smoothed by using a wood scraper. This should be done before the surface is sanded.

The scraper can be either pulled or pushed. It is held at an angle of about 75 deg. The degree will vary, depending on the way the scraper was sharpened. Fig. 9-7 shows a hand scraper in use. A cabinet scraper is the same type of tool, except that the blade is carried in a frame or body.

To sharpen a hand scraper, place it in a vise and draw file the edge square with the sides. Hone this edge and the sides on the oilstone until the corners of the edge are smooth and sharp. With the scraper again

Fig. 9-7. Using a wood scraper.

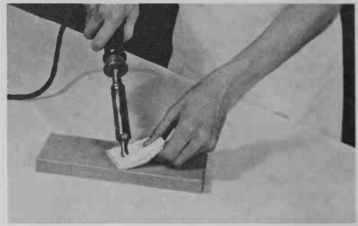


Fig. 9-9. Swelling a dent in wood with a damp cloth and soldering iron.

held in a vise, run a burnisher (hardened steel rod) along the edge. Hold the burnisher at a 90 deg. angle with the sides for the first stroke. Gradually tilt it for the next three or four strokes until it reaches an angle of about 85 deg., Fig. 9-8. Use a drop of oil on the burnisher and press it down firmly. This will form a slight hook or burr on the edge that will cut a fine "silky" shaving.

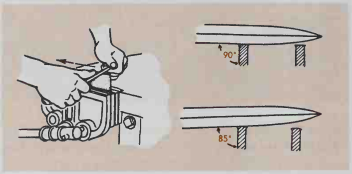


Fig. 9-8. Using a burnisher to turn edge of scraper. (Stanley Tools)

REPAIRING A WOOD SURFACE

To repair a small dent in the wood, place a drop of water in the depression. The water will soak into the wood fibers and swell them back to near their original position. When the dent is large, use a hot soldering iron and damp cloth, Fig. 9-9. Too much steaming or wetting is undesirable, especially when working with interior plywood. Allow the surface to dry thoroughly before sanding.

Checks, cracks and holes can be filled with stick shellac, wood putty, or plastic wood. These materials will not take stain properly and you must select a color that will match the final finish. Stick shellac comes in various colors. It can be melted and applied with an electrically heated knife. Plastic wood is also available in colors. A natural shade can be tinted with colors in oil as shown in Fig. 9-10. Place a bit of the color in oil on a paper towel and then mix a small portion of plastic wood with it using a putty knife. Keep the plastic wood can covered except when removing some material. If the plastic wood becomes too hard, it can be softened with lacquer thinner.

Fig. 9-10. Coloring plastic wood to patch a hole.

Plastic wood shrinks when it dries, so large patches should be filled above the level of the wood. Sand the patches smooth with the surface of the wood after the plastic has hardened.

THE FINAL TOUCH

When the wood surfaces are sanded smooth and are ready for finish, "soften" all the corners by removing the sharpness, using a pad of fine abrasive

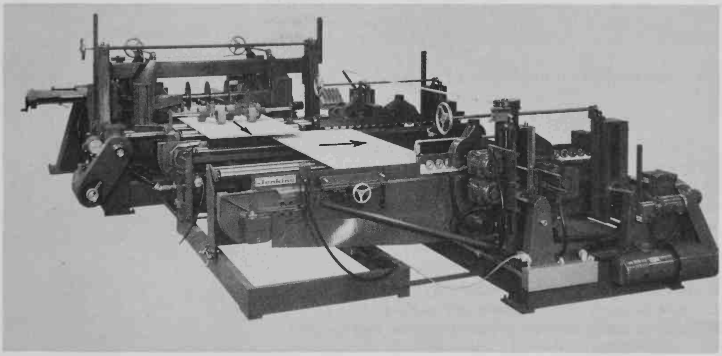
paper. With these very slightly rounded corners, there will be less danger of cutting through when rubbing down a coat of finish. Softened corners feel so much better "to the touch" and they also wear better. Be careful that the edge of the abrasive paper does not pick up wood splinters.

Finally, dust the project carefully and go over the surface with a damp sponge, Fig. 9-11. This will swell tiny wood fibers that have not been completely cut off with the abrasive paper and make them raise above the surface. This is called "raising the grain" and is a very important operation if a water stain is to be used. After the surface is dry, sand very lightly with a fine paper. Again, dust the project carefully and it is ready for the first coat of finish.

Fig. 9-11. Using a damp sponge to moisten surface and raise the wood grain.

QUIZ – UNIT 9

1. The three kinds of abrasives used for sanding wood are flint, garnet and ________ ________ .
2. Abrasives that are mined or quarried are called ________ materials.
3. The grade of an abrasive is determined by the size of the ________ .
4. The next finer grade to a number 1/2 abrasive paper would be a number ________ .
5. It is very important that the sanding motion be in the same direction as the ________ .
6. To sharpen a wood scraper you will need a file, an oilstone and a ________ .
7. Small dents in a wood surface can be removed by applying a few drops of ________ .



Industry Photo. Modern door and panel sizing machine – automatically cuts workpieces to exact size. It takes lots of skill and know-how to set up and maintain high production woodworking machines. (Jenkins, Div. Kohler-General)

Fig. 10-1. Cabinet for wood finishes.

Unit 10
WOOD FINISHING

After studying this unit, you will know:

1. **The proper sequence for applying finishing coats.**
2. **How to apply stains, fillers and sealers.**
3. **How to apply surface coats of lacquer and varnish.**

Wood finishing is an important step in the making of your project. Select and apply the finish carefully and you will add to its beauty as well as protect the surface of the wood.

You should do your share in maintaining the condition of the finishing materials and supplies. Always clean up your materials and return them to their proper place as soon as you have finished with

Fig. 10-2. Cleaning lip of can before replacing the lid.

them. See Figs. 10-1 and 10-2. Use care while working around other students' projects. Don't touch wet surfaces or "spatter" them with a finish you are using.

BRUSHES

There are many sizes, shapes and grades of brushes. The quality of the bristle makes a great difference in how well the brush will hold and spread the finish. A good bristle has a slight taper, is oval in cross-section and has flagged (split) ends as shown in Fig. 10-3. Nylon bristles and Chinese hog bristles have

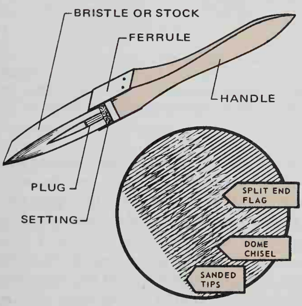


Fig. 10-3. Parts of a brush. Inset shows the tip of a quality brush.

these characteristics. Nylon bristles wear longer than China bristles, but cannot be used in lacquer and some synthetics.

Brushes that are in use from day to day may be kept suspended in a thinner or in some cases the finish being used. The rubber brush holders shown in the illustrations work well for shellac, lacquer and some synthetic finishes. They are not satisfactory for finishes with an oil base. It is best to thoroughly clean a brush after it has been used in varnish, in paint or enamel.

To clean a brush, first remove as much of the material as possible by pulling it over the edge of the container and then wiping with a rag or paper towel. Fig. 10-4. Wash the brush thoroughly in the correct thinner. Fig. 10-5. Then wipe off as much thinner as possible. Now wash the brush in soap and water, straighten the bristles and wrap in a paper towel. Discard oily rags by taking them to the school incinerator or store them in a covered metal container.

Fig. 10-4. Materials for brush cleaning.

STAINING

Staining is the first step to consider in the finishing schedule. It will emphasize or de-emphasize the grain and will add color to the wood surface. Most stains used on exterior woodwork have a preservative feature. Staining is not essential in obtaining a finished surface. Many woods have the most beauty when finished "natural" using clear finish.

Stains are generally classified in three groups. They are water, oil and spirit (alcohol base). There are two general types of oil stain: penetrating and pigmented. Penetrating stains are brushed on and the excess wiped off. Fig. 10-6. They should dry 24 hours and then be sealed with a thin coat of shellac. Pigment stains are applied in the same manner as penetrating stain. For heavy "toning" or "lightening"

Fig. 10-5. Thinners for wood finishing stored in safety cans.

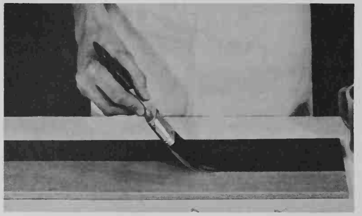


Fig. 10-6. Applying penetrating oil stain.

Fig. 10-7. Colors in oil are mixed with natural filler to obtain various shades.

effects, they are allowed to dry without wiping. They generally dry in twelve hours, and usually do not require a shellac sealer. Carefully study the manufacturer's directions and instructions on the label. Try out the stain on a scrap of wood before applying it to your project. Use turpentine or a turpentine substitute (mineral spirits) for a thinner.

PASTE FILLER

Walnut, oak, mahogany, and ash are some of the common hard woods that have an open grain (large pores). Fig. 10-8. For most finishes the pores need to

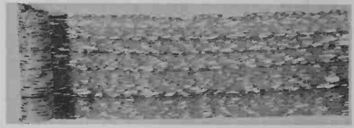
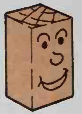


Fig. 10-8. The thin shaving of walnut shows the large pores that require a paste filler.

be filled with a paste filler. Some woodworkers prefer to apply a thin coat of shellac to the wood before the filling operation.

Paste filler contains silex (powdered quartz), linseed oil, turpentine and driers. It can be purchased in a natural shade (very light buff) and in several standard colors. Natural paste filler can be colored by adding colors ground in oil. Fig. 10-7. For a walnut shade use Vandyke brown and burnt umber. For mahogany use Vandyke brown and Venetian red. Thin the filler with turpentine or naphtha to a thin, creamy consistency.



WOODY SAYS:

"Most finishes are combustible, so keep them away from heat, sparks and open flames. Keep the room well ventilated. Don't leave finishing materials on your hands too long and avoid breathing vapors. Keep containers closed when not in use."

Apply the filler by pouring a small amount onto the wood surface; spread and rub it into the wood pores with the palm of your hand. In a short time (10-20 minutes) the filler will lose its wet appearance and the excess should be wiped off. Use a fairly coarse rag or a piece of burlap, wiping across the grain. Use a rag over a small pointed stick to remove filler from corners. Finish by wiping lightly with the grain. See Fig. 10-9. Inspect your work carefully. The filler should be in the pores and not on the surface of the wood. A stiff brush should be used when applying paste filler to large surfaces.

After the filler has dried overnight, it should be sanded lightly with a No. 180 finishing paper,

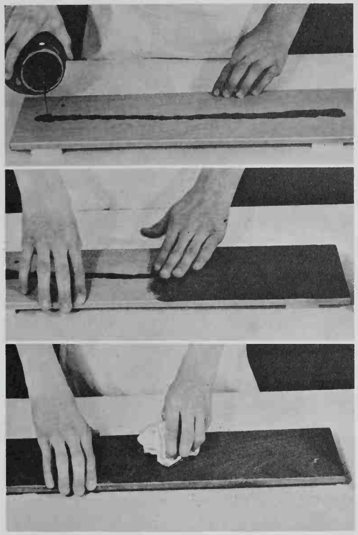


Fig. 10-9. Applying paste filler. Above. Pouring a small amount on the surface. Center. Spreading the filler. Below. Rubbing off across the grain.

working with the wood grain. Paste fillers will vary in the amount of time necessary to completely harden and be ready for additional costs of finish. Check the manufacturer's recommendation.

SEALERS

A sealer may be defined as the first coat of finish applied to close-grained woods such as pine, basswood, cherry and birch, or the first coat after paste filler on open-grained wood. Shellac is commonly used as a sealer. Lacquer based sealer (called sanding sealer) is designed for spraying but is easily brushed on smaller projects. There are many sealers that are especially designed for brush application that have excellent sanding qualities.

When using shellac (4 lb. cut) for a sealer it should be reduced with an equal amount of alcohol. Flow the shellac on with long brush strokes working from

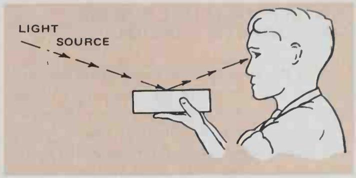


Fig. 10-10. How to inspect a surface.

the center of an area out over the edge. Do not brush back over the work. Allow the shellac to dry for at least two hours, then rub down with steel wool.

Shellac may also be used for the final finish. Apply second and third coats reduced about as much as the sealer coat. Allow overnight drying for all coats and rub each down with steel wool. After the last coat has been rubbed down apply a coat of paste wax.

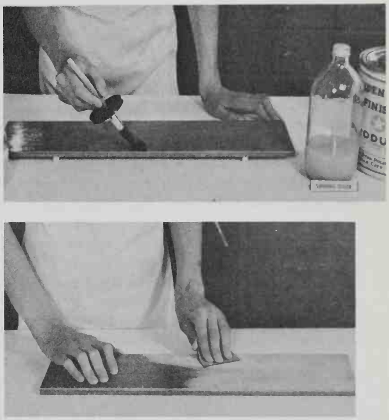


Fig. 10-11. Applying and cutting down sanding sealer.

Sanding sealer, Fig. 10-11, is brushed in the same manner as shellac. It will dry so you can handle your project in about 10 minutes and can usually be sanded with a dry No. 220 paper in 40 to 50 minutes.

SURFACE COATS OF LACQUER AND SYNTHETIC VARNISH

After the wood has been stained, filled and sealed, you are ready to apply the final surface finishes. Many new products are available in the area of synthetic varnishes and brushing lacquers. In using such finishes, always study the manufacturer's recommendations on the label. Some synthetic varnishes require a special thinner.

In applying lacquer and synthetic varnish, as in applying all finishes, the surfaces of your project should be clean. Brush them off carefully and then wipe with a tack-cloth (cloth treated so it will pick up lint and dust). Commercially prepared tack-cloths are available at reasonable cost.

Thin the finish if necessary, so it will flow easily. Dip the brush in the material so about one-third of the bristle length is immersed. Rub the brush against the inside edge of the container to remove the excess material. In applying finishing material to your project, move the brush over the surface with just enough pressure to cause the bristles to bend a little. Use fairly long strokes in the same direction as the grain of the wood. Work rather quickly, completing one section at a time. See Figs. 10-12 to 10-14 inclusive. Do not go back over a surface once it has been coated. Work from the center of a surface out over the edges. Keep the surface being coated between you and major light source so that you will have a good view of the work, Fig. 10-10.

Usually it is best to coat "hard-to-get-at" surfaces first. Brush edges and ends before the faces; bottoms before the tops. On some jobs you may find it best to coat the bottom surfaces, allow them to dry, then turn the project over and do the sides and top. You can make a tripod on which to rest the work by driving nails all the way through a thin piece of wood. Some pieces may be coated all over, then hung by a string or wire to dry.

On most projects, you should apply at least two coats of varnish or lacquer. The first coat should be cut down dry with 3/0 steel wool or No. 220 finishing paper. Clean the surface carefully and apply a second coat.

Rubber brush holders and mason jars save a lot of brush cleaning when these finishes are used a great deal. They are not "foolproof," however, and will

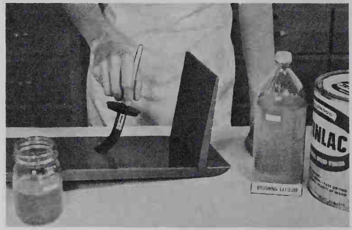


Fig. 10-12. Brushing a coat of lacquer.

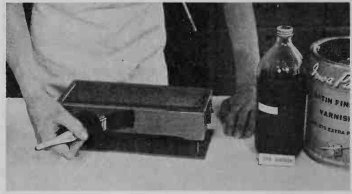


Fig. 10-13. Applying synthetic varnish.

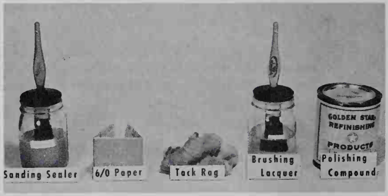


Fig. 10-14. Materials for lacquer finish.

require complete cleaning from time to time. Each time you finish using the material, you should wipe off the jar and bring the level of the finish to a mid-point on the bristles of the brush.

PENETRATING SEALER

A penetrating sealer is also referred to as a "rub-on" finish. It will produce a good finish and is

Fig. 10-15. Materials for applying a penetrating finish.

Fig. 10-16. Rubbing on penetrating finish.

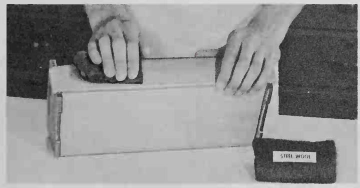


Fig. 10-17. Cutting finish with steel wool.

Fig. 10-18. Applying enamel.

very easy to apply. There are a number of brands available such as Dura-seal, Sealacell and Minwax.

For a natural finish on close-grained wood, pour a small amount of the finish on the surface and spread it with a soft cloth. Allow it to dry 24 hours, then rub it down with 3/0 steel wool. Second and third coats applied in the same manner but somewhat more sparingly, will give a smooth satin finish.

A penetrating seal can be applied over stain and/or filler. Use the same procedure as just described. Some woodworkers prefer to apply a coat of penetrating sealer before using paste filler.

After the last coat of sealer is rubbed down a coat of paste wax may be applied. See Figs. 10-15 to 10-17 inclusive.

PAINT AND ENAMEL

If you build your project of wood that does not have an attractive grain pattern, you may want to finish it with paint or enamel. Fig. 10-18. Seal any knots or sap streaks with shellac. Brush on a coat of enamel undercoater. After it is dry, sand it lightly, then apply a coat of enamel. If it is necessary to apply a second coat of enamel, the first coat should be cut lightly with fine abrasive paper. Use turpentine or mineral spirits for thinning these materials and also for cleaning the brush.

Latex emulsion paints make a satisfactory finish for wall shelves, picture frames, and other projects that are not subjected to hard usage. These paints have many advantages. They are easy to apply and dry quickly. They require no undercoat and water is used for thinner. They are available in a wide range of colors. Brushes should be cleaned in soap and water immediately after use.

SANDING AND RUBBING FINISHED SURFACES

Cutting down finished surfaces with abrasive paper, steel wool, or a powdered abrasive is an important part of producing a good finish. If brush marks, dust specks and other imperfections are not removed, they will continue as a part of the finish and even become more noticeable after the next coat is applied.

First coats should be rubbed with dry finishing paper or steel wool. At this stage the finish is quite thin and water or other lubricants could easily get under the surface. Use a small piece of abrasive paper and fold it twice into equal sections. This makes a good "pad" with the grain side of one flap interlocking with the paper side of the other flap. Always clean the surface carefully after rubbing, especially when steel wool is used.

When cutting the second coat with abrasives (and any succeeding coats) you will find that a wet-or-dry silicon carbide paper used with water works very well. A 400 or 500 grade paper will remove imperfections and leave a dull sheen to the surface. A brighter sheen can be obtained by rubbing with pumice stone and oil, or rottenstone and oil. A commercially prepared rubbing compound is recommended for polishing the final coat of lacquer. Finishes should always be rubbed in the direction of the wood grain.

Finishes are available that dry to a soft, rubbed-effect lustre and do not require a final rubbing or polishing.

Fig. 10-19. Skilled workers produce special effects on high quality furniture. (Thomasville Furniture Industries, Inc.)

FINISHING SCHEDULES

It is good practice to develop a finishing schedule, and include it in your plan of procedure. This will make it easy for your teacher to check your ideas and make suggestions.

Listed below is a sample of a schedule you might prepare for a lacquer finish on walnut, mahogany or other open-grained wood:

1. Apply a pigment oil stain. Dry at least 12 hours.

Skilled workers spraying final coat of lacquer in a modern furniture plant. Units rest on pallets which are carried on a conveyor line. (Mersman Bros. Corp.)

2. Fill with a paste filler, colored to match the stain. Dry overnight.
3. Sand very lightly with No. 180 paper and clean the surface.
4. Brush one coat of sanding sealer. Dry 1 hour.
5. Rub down sanding sealer with No. 220 paper, brush off surface and wipe with a tack rag.
6. Apply clear brushing lacquer. Dry 4 hours.
7. Rub with No. 220 paper or 3/0 steel wool.
8. Apply second coat of clear brushing lacquer. Dry overnight.
9. Rub with polishing compound.

FINISHING IN INDUSTRY

Brush application of finishes is too slow and expensive for modern production lines. Spray finishing with fast drying lacquers and synthetics helps to make it possible to purchase quality products at moderate prices.

Small wooden objects such as golf tees, knobs, buttons, fishing plugs, beads and blocks are finished by "tumbling." In this process the parts are placed in a large drum or barrel with especially prepared enamels and lacquers. The drum is turned at a speed of about 25 rpm, causing the small parts to roll and tumble over each other as they dry. This results in a smooth, satiny finish that is impossible to duplicate by any other method.

Other production methods of finishing include: roller coating, dipping and flow coating. Some use is made of these methods to finish woodwork but they are more adaptable to metal parts.

A study of the whole area of finishing could easily become a course in itself. Entire books are devoted to the subject. The chemical industry continues to provide many new and improved types of synthetic finishes to extend this study. The wood finisher and painter of today faces a great challenge as he keeps abreast of many new techniques and materials.

QUIZ – UNIT 10

1. One of the important qualities of a true brush bristle is that it has ________ ends.
2. After paste wood filler has set-up for 10 or 20 minutes it should be wiped off ________ the grain of the wood.
3. Mahogany is one of the common hard woods that has an ________ grain.
4. Paste wood filler should be thinned with naphtha or ________ .
5. A rag that has been especially treated to pick up lint and dust particles is called a ________ .
6. If the shellac is too heavy for easy brushing it should be thinned with ________ .
7. Sanding sealer should be cut down with a dry paper of about ________ grade.
8. A penetrating sealer should dry ________ hours before being cut down and recoated.
9. Undercoater should dry thoroughly and then be ________ before a coat of enamel is applied.
10. Latex emulsion paints should be thinned with ________ .
11. Water or oil should not be used in rubbing down a finish until the ________ surface coat has been applied.
12. Mineral spirits is a petroleum product used as a substitute for ________ .
13. The liquid part of a paint is called the ________ .

Unit 11
DRILL PRESS, JIG SAW, BAND SAW

After studying this unit, you will know:
1. **How to use the drill press.**
2. **How to install blades in a jig saw.**
3. **How to make internal cuts on a jig saw.**
4. **How to operate a band saw efficiently and safely.**

THE DRILL PRESS

The size of a drill press is indicated in terms of diameter of the largest circular piece which may be drilled through the center while on the table of the drill press. The 15 in. drill press shown in Fig. 11-1 will drill a hole in the center of a round piece 15 in. in diameter. A drill press is used chiefly for drilling holes, but with special attachments it may be used for drum sanding, mortising, shaping and routing.

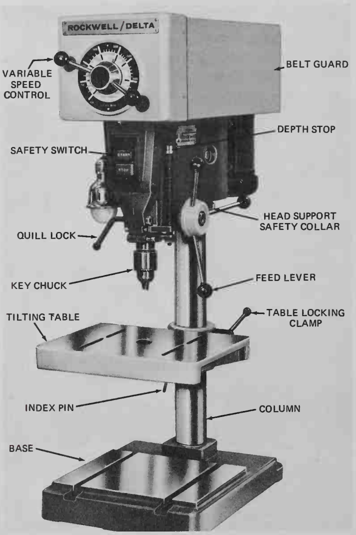


Fig. 11-1. Photo of a drill press. (Rockwell Mfg. Co.)

In preparing to use a drill press, lay out and mark the center of the hole in the same manner as when working with hand tools. Insert a bit into the key chuck as far as it will go, and turn the chuck by hand until the jaws are snug on the drill. Use the chuck key to tighten the chuck. Always remove the chuck key from the chuck immediately after use.

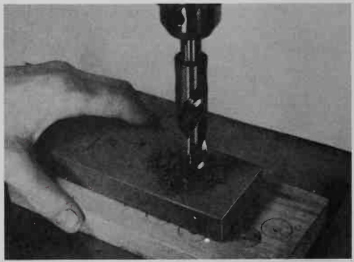
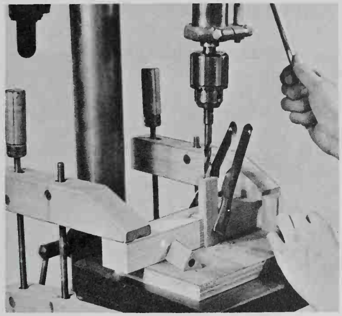


Fig. 11-2. Boring a 3/4 in. hole.

Adjust the height of the table and the depth stop so that the vertical travel of the drill will be correct for your work. The center hole of the table should be directly under the bit.

Use the slowest speed for holes that are over 1/4 in. in diameter. Smaller diameters can be drilled



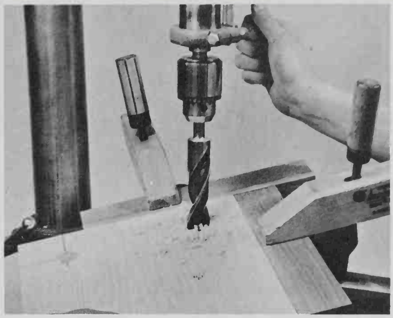


Fig. 11-3. Left. Special setup for drilling hole in small part. Drill the hole half way through, reverse the piece and finish from the other end. Fig. 11-4. Right. Drilling holes at an angle by tilting the table. Strips clamped on the table make it easy to locate a hole in each corner of the stock.

safely at higher speeds. Check with your instructor before changing the speed of the drill press.

Hold the work firmly in the correct position on the table. Turn on the drill and feed the bit into the work with the feed lever. Use just enough pressure so the drill cuts easily. For large holes in small pieces of wood you should mount the work in a drill press vise, or clamp it to the table.

If the hole is to go all the way through the stock, use a piece of scrap stock under your work. See Fig. 11-2. When drilling deep holes with a small bit, withdraw bit several times to remove cuttings.

Always stop the machine before making any adjustments. Special setups are shown in Figs. 11-3 and 11-4.

THE JIG SAW

The size of a jig saw (sometimes called a scroll saw) is determined by the distance from the blade to the over arm. You can cut to the center of a 48 in. circle on a 24 in. saw. The jig saw is an excellent tool to use for cutting sharp curves and various shapes in thin wood, Fig. 11-5.

CUTTING ON THE JIG SAW

Loosen the guide post and position the guide assembly so that the hold-down springs rest firmly on the top of the work. Start the saw and feed the work forward into the blade. You will get the smoothest cut if you feed the work slowly. Keep the blade cutting just on the outside or "waste side" of the line. Give the blade plenty of time to cut its way clear as you go around corners.

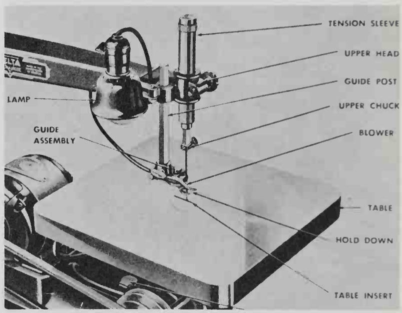


Fig. 11-5. Parts of a jig saw.

Before cutting complicated designs, you should work out the "route" you will follow. This will often eliminate the need to back out of long cuts, or make sharper turns than the blade permits. Drilling small holes in the waste stock at corners will often make the cutting easier. See Figs. 11-6, 11-7 and 11-8.

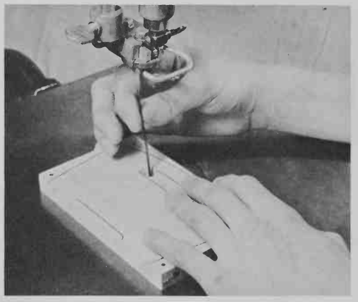


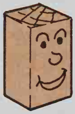
Fig. 11-6. Threading jig saw blade for internal cutting. Detach blade from upper chuck and roll machine by hand until the blade is at its lower point before threading the blade through the work.

Jig saw blades vary in length, width and thickness. They also vary in the number of teeth per inch and the shape of the teeth. Study a manufacturer's catalog for suggestions on blade selection for special jobs. Most of your work can probably be done with a blade of the following size: .020 in. thick x .110 in. wide – 15 teeth per inch.

INSTALLING BLADE IN JIG SAW

To install a blade in a jig saw remove the table insert and turn the saw by hand until the lower chuck is at its highest point. Loosen the thumbscrew of the lower chuck and see that the jaws are clean. Insert the blade about 1/2 in. with the teeth pointing downward. Hold the blade straight up-and-down and tighten the thumbscrew.

GENERAL SAFETY RULES FOR OPERATING WOODWORKING MACHINES



WOODY Says:

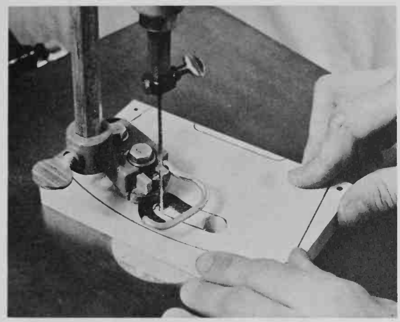
"As a beginning student you will be expected to do most of your work with hand tools. There will be times, however, when a basic machine operation will save time and be appropriate for your work.

Whether or not you are permitted to use the machines will depend on your own maturity and ability and the policies established by your instructor.

Before operating any power tool or machine you must become thoroughly familiar with the way it operates and how it is used. As you learn to use a machine the correct way, you will also be learning to use it the safe way.

You should know and understand the following general safety rules for power machine operation. In addition, you should also study and follow safety rules that apply to specific machines.

1. Always be sure you have the instructor's approval to operate a machine. He knows you and the machine and can best make the decision as to whether you have "what it takes" to operate it safely.
2. Wear snug-fitting clothing. Roll up your sleeves, tuck in your tie, wear a shop apron and tie it snugly.
3. You must be wide awake and alert. Never operate a machine when you are over tired or ill.
4. Think through the operation before performing it. Know what you are going to do, and what the machine will do.
5. Make all the necessary adjustments before turning on the machine. Some adjustments on certain machines will require the instructor's approval.
6. Never remove or adjust a safety guard without the instructor's permission.
7. Keep the machine tables and working surfaces clear of tools, stock, and project materials. Also keep the floor free of scraps and excessive litter.
8. Allow the machine to reach its full operating speed before starting to feed the work.
9. Feed the work carefully and only as fast as the machine will cut it easily.
10. If a machine is dull, out of adjustment, or in some way not working properly, shut off the power immediately and inform the instructor.
11. You are the one to control the operation. Start and stop the machine yourself. If someone is helping you, be sure they understand this and know what they are expected to do and how do do it.
12. Do not allow your attention to be distracted while operating a machine. Also, be certain that you do not distract the attention of other machine operators.
13. Stay clear of machines being operated by other students. See that other students are "out of the way" when you are operating a machine.
14. When you have completed an operation on a machine, shut off the power and wait until it stops before leaving the machine or setting up another cut. Never leave a machine running and unattended.
15. Machines should not be used for trivial operations, especially on small pieces of stock. Do not play with machines.
16. Do not "crowd around" or wait in line to use a machine. Ask the present operator to inform you at your work station when he has finished. Common standards of courtesy may slow you down a little but they will make the shop a more pleasant and safer place to work."



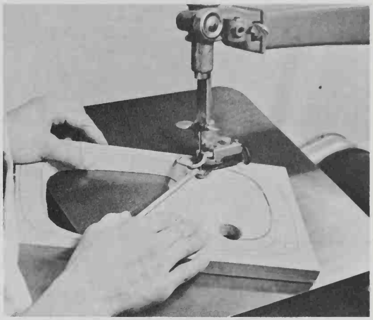


Fig. 11-7. Left. Making an internal cut. Two pieces are being cut. Notice the nails in the waste stock. Fig. 11-8. Right. Making an angle cut. Table and hold down have been tilted 20 degrees.

Loosen the thumbscrew on the upper chuck. Pull the chuck down over the blade and tighten the thumbscrew. Do not use pliers or wrenches to tighten thumbscrews. Position the tension sleeve so it is about 3/4 in. above the upper chuck. Roll the saw over a few turns by hand to see if the blade is clear and runs up and down in a straight line.

Adjust the guide assembly so the blade runs freely on its sides, and the blade support roller just touches the back of the blade. Replace the table insert.

THE BAND SAW

The size of a band saw, Fig. 11-9, is derived from the diameter of its wheels. These wheels are fitted with rubber tires that provide traction for the blade and cushion the teeth. The upper wheel is adjustable up and down to provide tension on the blade. It can also be tilted in or out so that the blade will run in the center of the wheel. This is called "tracking the blade."

The blade guide assemblies are important parts of the band saw. One is located above and the other below the table. The guide above the table, Fig. 11-10, can be moved up and down to adjust for various thicknesses of stock. When perfectly adjusted, the blade guides do not contact the blade except when a piece of wood is being cut. It's a "tricky" job to adjust and line up the band saw blade and guides.

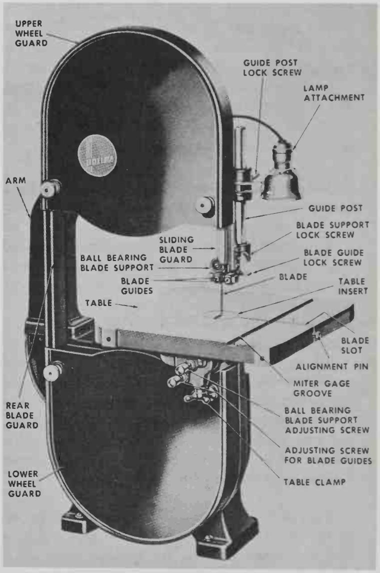


Fig. 11-9. Parts of a band saw.

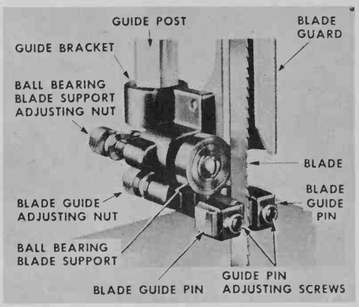


Fig. 11-10. Parts of band saw upper guide assembly.

Always check with your instructor before making any of these adjustments.

The band saw is designed to cut curves and irregular shapes in thicker and heavier stock than can be cut on a jig saw. It has a wider blade (usually about 3/8 in.) which cuts faster but not as smooth. The minimum turning radius varies with the blade width and set of the teeth. A 3/8 in. blade should not be used to cut a radius smaller than 1 1/4 inches.

The band saw is often used to rough out stock before planing and jointing.

Some band saws are equipped with rip fences and miter gages, so they may be used in about the same manner as a circular saw.

CUTTING ON THE BAND SAW

Before turning on the machine, adjust the upper guide assembly so that it is about 1/4 in. above the top surface of your stock. Turn on the machine. Use your right hand to push the stock into the saw blade, and your left hand to guide the stock. Because of the rougher cut of the band saw you should stay at least 1/16 in. away from the line.

Make short cuts before long ones as shown in Fig. 11-11. This will prevent the need to back out of a long cut. When possible, cut through waste stock rather than back out. Make several relief cuts before cutting a sharp curve as shown in Fig. 11-12. If the layout is complicated it should first be "roughed out," cutting only those curves that can be handled easily. After completing these cuts, go back over the work and cut the sharper curves and smaller detail.

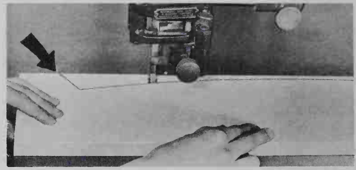


Fig. 11-11. Cutting procedure on the band saw. Arrow points to the cut that was made first.

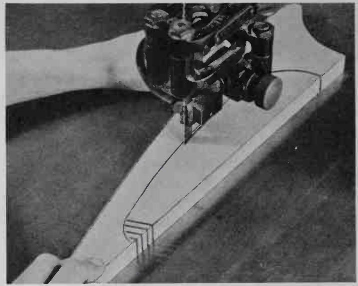
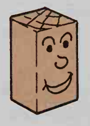


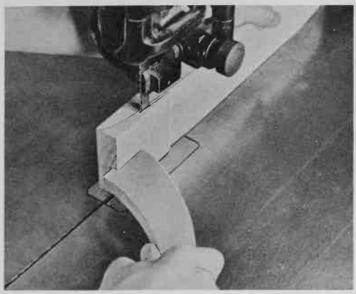
Fig. 11-12. Relief cuts are made before cutting sharp curves. Notice that the blade is cutting about 1/16 in. on the waste side of the line.

BAND SAW SAFETY RULES



WOODY SAYS:

"1. Adjust the upper guide assembly so it is 1/4 in. above the work before turning on the saw.
2. Allow the saw to reach full speed before starting to feed the work into it.
3. The stock must be held flat on the table.
4. Feed the saw only as fast as the teeth will remove the wood easily.



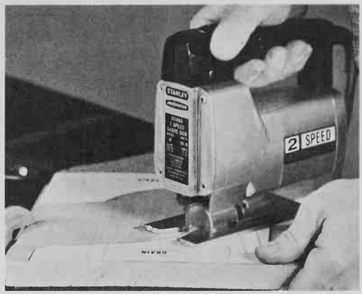


Fig. 11-13. Left. Using a push stick to maintain a 3 in. margin of safety. Fig. 11-14. Right. Electric saber saw. The tool is well suited for cutting curves and openings in large sheets of plywood.

5. Maintain a 3 in. margin of safety, Fig. 11-13. (This means that the hands should always be at least three inches away from the blade when the saw is running.)
6. Plan saw cuts to avoid "backing out" of curves, wherever possible.
7. Make turns carefully and do not turn radii small enough to cause twisting of blade.
8. If you hear a clicking noise, turn off the machine at once. This indicates a crack in the blade.
9. Round stock should not be cut unless mounted securely in a jig or hand screw.
10. Keep saw evenly set and sharp."

QUIZ – UNIT 11

1. A 14 in. drill press will have a measurement of ________ in. from the center of the chuck to the column.
2. The bit is mounted in the ________ of a drill press.
3. The movable sleeve that carries the spindle of the drill press is called a ________ .
4. Holes can be bored at an angle on the drill press by tilting the ________ .
5. The size of a jig saw is determined by the distance from the blade to the ________.
6. The blade of a jig saw should be installed with the teeth pointing ________ .
7. A screw that is designed for tightening with the thumb and fingers is called a ________ .
8. The blade support roller on the jig saw should just touch the ________ of the blade.
9. A jig saw blade for general purpose work will have about ________ teeth per inch.
10. The size of a band saw is determined by the size of its ________ .
11. Tilting the top wheel of the band saw in or out to make the blade run in the center of the tire is called ________ the blade.
12. The upper blade guide assembly should be positioned about ________ in. above the top surface of the work.
13. When operating the band saw you should maintain a ________ in. margin of safety.

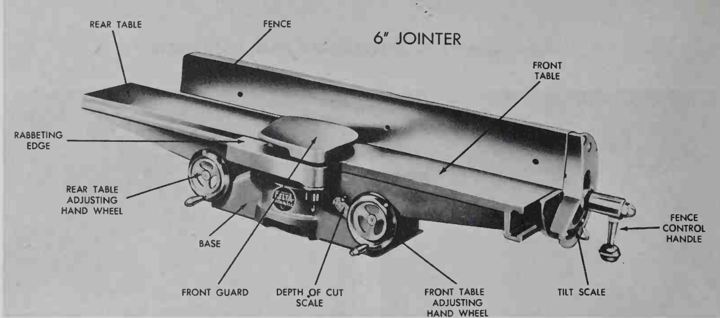


Fig. 12-1. The parts of a jointer. (Rockwell Mfg. Co.)

Unit 12

JOINTER AND CIRCULAR SAW

After studying this unit, you will know:

1. **The makeup and adjustment of a wood jointer.**
2. **How to perform basic operations on the jointer.**
3. **How to do ripping and crosscutting on the circular saw.**
4. **The safety rules for operating a jointer and circular saw.**

THE JOINTER AND ITS PARTS

The wood jointer is a power driven machine used to plane or finish edges and surfaces of lumber. A jointer can also be used to cut chamfers, bevels, tapers and rabbets.

Principal parts of a jointer are shown in Fig. 12-1. The cutter head (not shown in the photo) holds three knives and revolves at a speed of about 4500 rpm. The size of the jointer is determined by the length of these knives. This also determines the maximum width of stock the jointer will smooth at one time.

ADJUSTING THE JOINTER

The three main parts that can be adjusted are the front table, the rear table and the fence. The rear table must be level with the knife edges at their highest point of rotation. This is a critical adjustment. Be sure to check with your instructor before making any changes in the setting.

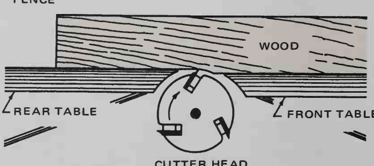


Fig. 12-2. How a jointer works. Note the direction of the wood grain.

The fence guides the stock over the table and knives. When jointing an edge or squaring stock, it should be perpendicular to the table surface. The fence can be tilted to other angles when cutting chamfers or bevels.

To make a cut on the jointer the front table is set below the level of the knives and rear table. Most jointers have a scale that indicates this distance, which is referred to as the "depth of cut."

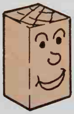
JOINTING AN EDGE

Examine your stock and determine the direction of the grain. Turn it to feed into the machine as shown in Fig. 12-2. Be certain that the fence is tight and the guard is in position. Set the depth of cut at about 1/16 in. and start the machine.

Place the stock on the table, hold it against the fence and start the cut as shown in Fig. 12-3. When a foot or more of the stock has passed over the knives, "step" the left hand across the knives and press the stock against the fence and rear table as you continue to move it forward.

JOINTER SAFETY RULES

(These are in addition to general safety rules for operating power-driven machines.)



WOODY SAYS:

"1. Be sure you have the instructor's approval to operate the machine.

2. Before turning on the machine, make adjustments for depth of cut and position of fence. Do not adjust the rear table or remove the guard.

3. The maximum cut for jointing an edge is 1/8 in. and for a flat surface, 1/16 in.

4. Stock must be at least 12 in. long. Stock to be surfaced must be at least 3/8 in. thick, Fig. 12-6.

5. Feed the work so the knives will cut "with the grain." Use only new stock that is free of knots, splits and checks.

6. Keep your hands away from the cutter head even though the guard is in position. Maintain a 4 in. margin of safety.

7. Use a push block when planing a flat surface.

8. Do not plane end grain.

9. The jointer knives must be sharp. Dull knives will vibrate the stock and may cause a kickback."

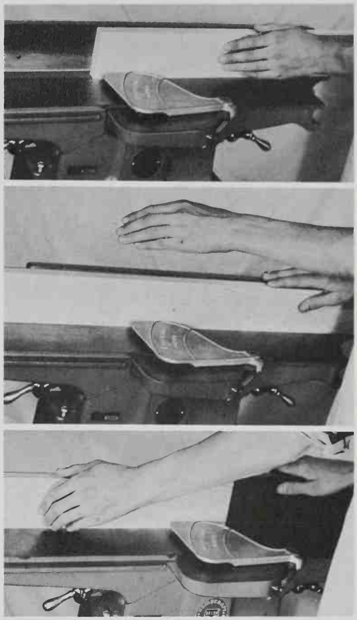


Fig. 12-3. Jointing an edge. Above. Starting the cut. Center. Stepping left hand over the knives. Below. Finishing the cut.

For long pieces continue to feed the stock with both hands, first moving one hand back to a new position and then the other. You can finish the cut with the left hand as shown in Fig. 12-3, or you may step the right hand across the knives and finish the cut with both hands.

By following the above procedure, your hands do not pass directly over the knives. Neither is it necessary for them to come closer than four inches to the knives, thus maintaining the margin of safety recommended for the jointer. See Fig. 12-4.

PLANING A SURFACE

Turn your stock so you will be feeding the grain of the wood in the right direction. If there is some warp

Fig. 12-4. Using push sticks to joint a small strip. Push stick in the right hand is picked up when the end of the stock comes onto the front table.

in the board, turn the concave (dished in) surface downward so that the stock will not rock on the table. Set the depth of cut at about 1/32 in., check the fence and guard, and turn on the machine.

Place the stock on the front table and move it into the knives. The left hand should be kept well back of the knives and then "stepped" over them to hold the stock down on the rear table. Finish the cut by placing a "push block" on the end of the board as shown in Fig. 12-5.

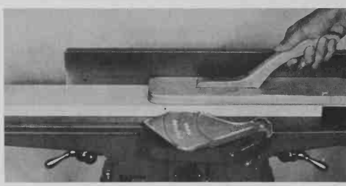


Fig. 12-5. Planing a surface with the aid of a push block.

Thin, narrow strips can be surfaced with considerable safety by using the setup shown in Fig. 12-6. Here a feather board is clamped to the fence so that it applies firm pressure to the stock as it passes over the knives. Feed the stock in about half way, then move around to the rear table and pull it through. The stock should be at least 2 ft. long.

SIZE LIMITATIONS

Small pieces of stock cannot be machined safely on a jointer. For most machines the minimum length is 12 in. The minimum thickness that should be surfaced is 3/8 in. Even with these sizes and larger pieces you will need to use push sticks and push blocks to maintain the 4 in. margin of safety.

Fig. 12-6. Surfacing a thin strip. Feather board insures safe and accurate work.

Plan your work so that you will machine your stock while it is in large pieces. After it is cut into small pieces you should use hand tools.

THE CIRCULAR SAW

The size of a circular saw is determined by the largest blade it will take. A saw that takes a 10 in. diameter blade, for example, would be called a 10 in. circular saw.

There are three principal types of blades: Rip, Crosscut and Combination. A combination blade will do both ripping and crosscutting, and is the type most often used in the school shop.

Parts of a circular saw are shown in Fig. 12-7.

Before stock is cut on the circular saw, it must be planed or surfaced so it will lay flat on the table. At least one edge must be planed or jointed straight and true.

RIPPING STOCK TO WIDTH

Raise the saw blade until it projects above the table a distance equal to the thickness of the stock

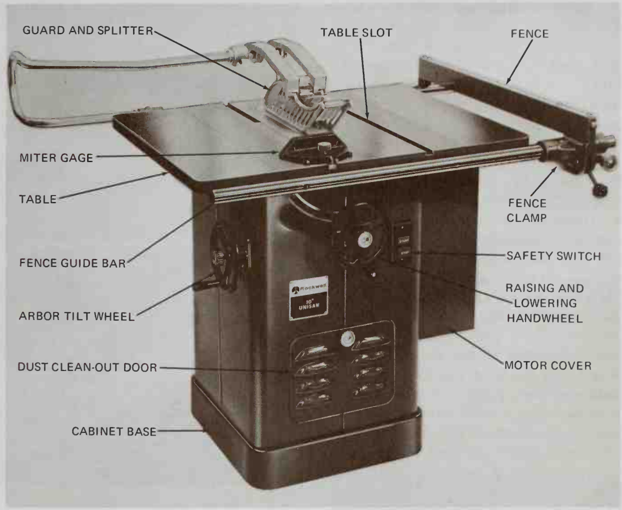


Fig. 12-7. Parts of a circular saw. (Rockwell International)

plus 1/4 in. Unlock the fence and move it along the guide bar to the required width. For a very accurate setting check the measurement between the fence and the point of a tooth on the blade that is set (bent) toward the fence. Lock the fence in position, place the guard over the blade, and start the machine.

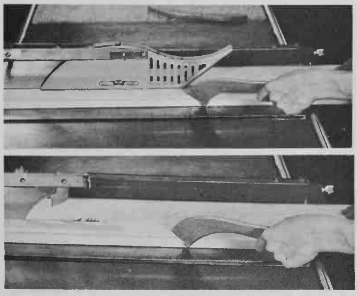


Fig. 12-8. Ripping stock to width. Guard has been raised in the lower picture to show splitter and blade height.

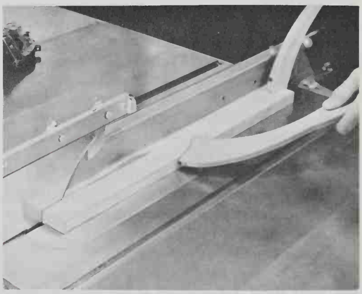


Fig. 12-9. Using push sticks to rip narrow strip. Guard cannot be used.

Place the stock flat on the table with the straight edge against the fence and move it into the blade. Continue a steady feed through the entire cut. Keep your hands at least 4 in. away from the blade even though it is covered by a guard. On narrow stock, use push sticks to maintain this margin of safety, Fig. 12-9. When the saw is operating, stand slightly to one side of the cutting line.

CUTTING STOCK TO LENGTH

Square a line across the stock where the cut is to be made. Set the height of the saw the same as for ripping (1/4 in. above the work). Move the fence to one side and well out of the way. Place the miter gage in the table slot and set it at a right angle (90 deg. mark on the protractor scale).

Hold the straightedge of the stock against the miter gage with your left hand, Fig. 12-10. Align the cutting marks with the saw blade so that the saw kerf will be on the waste side of the line. Lower the guard over the saw and turn on the motor. Grasp the knob of the miter gage in the right hand and move the stock through the cut as shown in Fig. 12-12. Turn off the saw immediately and wait for the blade to stop before leaving the machine or setting up for the next cut.

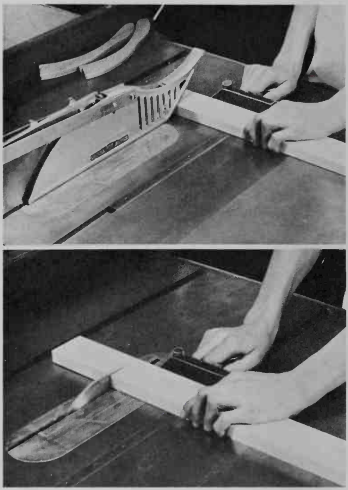


Fig. 12-10. Cutting stock to length. Guard has been removed in lower picture to show height of saw.

Maintain the same margin of safety (4 in.) as for ripping. The clamp attachment for the miter gage, shown in Fig. 12-11, increases the accuracy and safety of crosscutting operations.

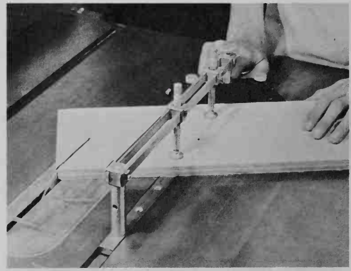


Fig. 12-11. Using a clamp attachment to cut an angle. The guard can be used for this operation.

RESAWING

Resawing is a ripping operation where the thickness of a board is reduced or the board is made into two thinner pieces. If the width of the board does not exceed the maximum height that the blade can be raised, the operation can be completed in one cut. For wider boards set the saw to cut a little above the center line and make two cuts. Keep the same face of the stock against the fence for both cuts. Fig. 12-12 shows a resawing setup with the first cut just being started. A feather board increases the accuracy and safety of resawing operations.

A feather board can be made by ripping a series of saw kerfs about 1/4 in. apart in the end of a board and then trimming it off at about a 30 deg. angle. The strips that are formed serve as a series of "springs" that apply a smooth, even pressure.

Beginning students should perform their first resawing operations by setting the saw slightly below the center of the work, leaving about 1/4 in. to hold the two pieces together after the second cut. The pieces can then be cut apart with a handsaw.

Fig. 12-12. Resawing with the aid of a feather board. Notice that the feather board is positioned just ahead of the saw. The clamp holding the feather board does not show in the picture.

CUT RABBETS WITH THE GRAIN

A rabbet is made with two ripping cuts. Lay out the rabbet on the end of the stock, then measure carefully the height of the saw and the fence setting for each cut. Fig. 12-13 shows the second cut of a rabbet being made. If the order of making the cuts is reversed there is a possibility of a kickback of the waste strip since it would be trapped under the work between the balde and the fence.

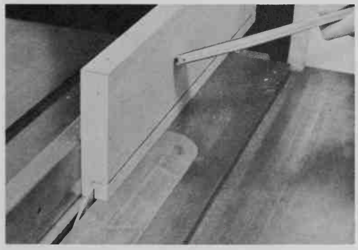


Fig. 12-13. Cutting a rabbet. This shows the second cut being made.

THE DADO HEAD

A dado head is designed to cut dados and grooves. It consists of two outside blades with chippers in between. The thickness of the dado can be varied by the number and thickness of the chippers used. Fig. 12-14 shows a dado head being set up. The chippers have wide cutting edges and must be positioned in the

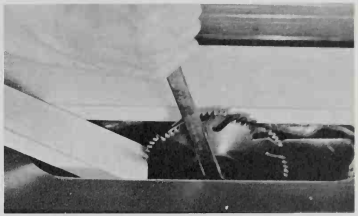


Fig. 12-14. Tightening the dado head.

gullets of the outside blades. A special table insert must be used with a dado head. Always have your instructor check the dado head setup before turning on the power.

Dados and grooves can also be made with the regular saw blade by making a series of cuts and then finishing with a chisel or router plane.

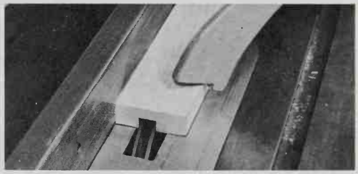
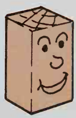


Fig. 12-15. Cutting a groove with the dado head.

CIRCULAR SAW SAFETY



WOODY SAYS:

"1. Be sure the blade is sharp and the right one for your work.

2. Be sure the saw is equipped with a guard and a splitter, and use them.

3. Set the blade so it extends only about 1/4 in. above the stock to be cut.

4. Stand to one side of the operating blade and do not reach across it.

5. Maintain a 4 in. margin of safety. (Do not let your hands come closer than 4 in. to the operating blade even though the guard is in position.)
6. Stock must be surfaced and at least one edge jointed before being cut on the saw.
7. The position of the stock must be controlled either by the fence or the miter gage. Never cut stock free hand.
8. Use only new stock that is free of knots, splits and warp.
9. Stop the saw before adjusting the fence or blade.
10. Do not let small scrap cuttings accumulate around the saw blade. Use a push stick to move them away."

QUIZ – UNIT 12

1. The size of a jointer is determined by the length of the ________.
2. The depth of cut of a jointer is controlled by the setting of the ________ ________.
3. When jointing an edge the fence of the jointer should set at a ________ deg. angle with the table.
4. The minimum length of stock that should be cut on the jointer is ________ inches.
5. When starting to plane an edge joint, the stock should be placed on the front table of the jointer and pressed firmly against the ________.
6. When surfacing a board that is warped, the concave surface should be turned ________ .
7. Two general types of circular saws are the tilting arbor and the tilting ________.
8. The height of the saw blade should be about ________ in. above the stock being cut.
9. To square the end of a piece of stock the miter gage should be set on the ________ deg. mark of the protractor scale.
10. When a 3/4 in. board is cut in such a way as to produce two boards 5/16 of an inch thick the operation is called ________ .

Using an auxiliary table on the circular saw. Parts are being cut to exact length. Table unit is guided by strips that slide in the saw table slots. Guard over blade has an acrylic plastic top so cutting action can be observed. (See arrow.)

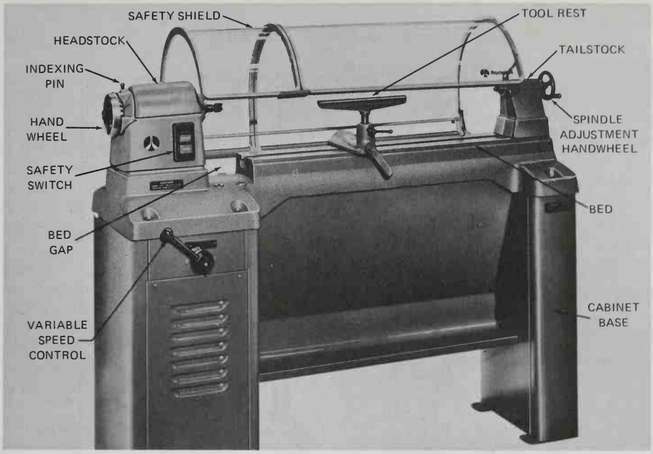


Fig. 13-1. Parts of the wood turning lathe. (Rockwell International)

Unit 13
WOOD LATHE

After studying this unit, you will know:
1. **How the wood lathe operates.**
2. **How to mount work for spindle turning.**
3. **How to turn small bowls and trays.**

A wood lathe is a power tool on which the wood is mounted and rotated against a cutting edge.

The size of a wood lathe is determined by the largest diameter stock that can be turned on the lathe. The basic parts of a wood lathe are called out in Fig. 13-1.

When stock is mounted between lathe centers and turned, the operation is called spindle turning. This type of turning is used to produce table and chair legs, lamp stems, ball bats and other long round objects. Faceplate turning, where the stock being turned is mounted on the faceplate, is the other general type, and is used for bowls, wheels and other disc-shaped objects.

MOUNTING STOCK FOR SPINDLE TURNING

The stock should be approximately square. Allow an extra inch of length so that the piece can be trimmed after the turning is complete.

Locate the center of each end by drawing diagonal lines across the corners. On the end that will take the spur or drive center, drill a small hole and make saw cuts, Fig. 13-2. Plane off the corners of stock that is more than 2 in. square. Place the stock on the lathe bed and drive the spur center into the work.

Place the spur center, with the wood attached, into the spindle of the head stock and slide the tail

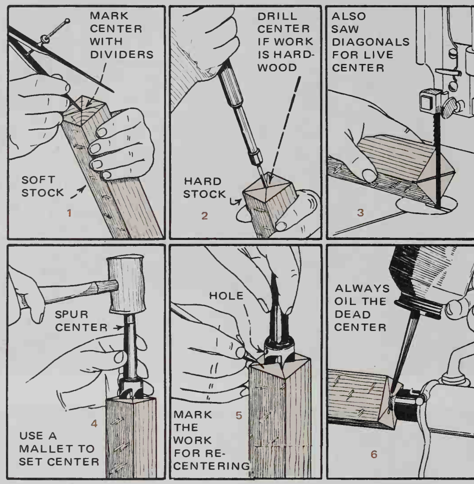


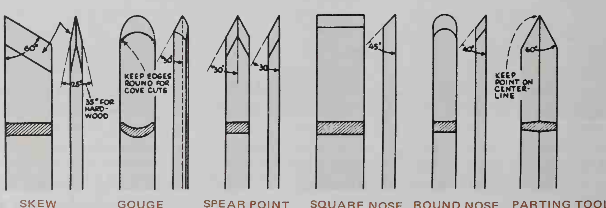
Fig. 13-2. Preparing spindle work for mounting.

stock into position. Lock the tail stock to the lathe bed and feed the cup center (sometimes called the dead center) into the stock while turning the lathe by hand. This will form a "bearing" that should be at least 1/16 in. deep. Back out the cup center, lubricate it with oil or wax and then move it back into position. Leave a very slight clearance so that the lathe turns easily. Lock the tail stock spindle clamp.

THE TOOL REST

The top of the tool rest should be smooth and free of nicks so lathe tools, Fig. 13-3 (also called chisels) can be easily moved along this surface. For most spindle turning the rest should be just slightly above the center of the work. It should clear the work by 1/8 to 1/4 in. Stop the lathe and reposition the tool

Fig. 13-3. Wood turning chisels.



rest as the diameter of the work is reduced. Remove the tool rest when sanding or polishing the work.

SPINDLE TURNING

Set the lathe on the lowest speed and turn it by hand to see that the tool rest clears the stock. Select a large gouge and turn on the power.

Place the gouge on the tool rest holding it firmly, using the method shown in Figs. 13-4 or 13-5. By turning the gouge slightly you will be able to direct the flow of shavings to the side. Take light cuts, moving from left to right across the work until the tool cuts smoothly, indicating that a cylinder has been formed.

To turn the cylinder to a prescribed diameter, use the caliper and parting tool as shown in Fig. 13-6. The parting tool is held with the edge on the tool rest. If the cylinder is smooth and round you can place the caliper on the work while it is turning. Cut with the parting tool until the caliper just slips over the work. Space several of these cuts along the work and then use a large skew to cut down to these diameters. The parting tool can also be used to square off the ends to the required length.

The expert woodturner will use gouges and skews to make shearing cuts that result in a very smooth surface. The beginner, however, should limit his work to scraping cuts produced by holding the tools level and touching the work directly in front of the tool rest. Concave cuts are made with the round nose and convex cuts with the spear point or skew. A single beveled tool, such as the spear point, should be used with the bevel side down.

After the work is turned to a smooth cylinder you can increase the speed of the lathe. How fast you can safely turn the work will depend on its diameter. Large diameter stock must be turned at slow speed. Use good judgment as you select higher speeds, and secure advice from your instructor.

MOUNTING WORK ON FACEPLATE

When screw holes will not detract from the finished turning, the stock can be fastened directly to the faceplate. Usually, however, it is better to glue the work to a backing block.

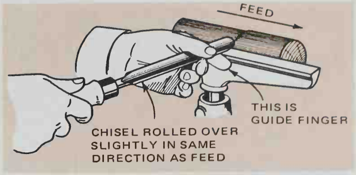


Fig. 13-4. Using a gouge to turn down a cylinder.

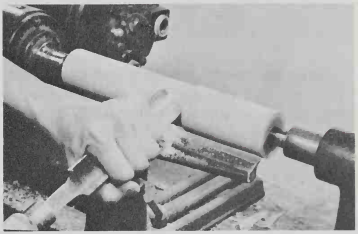


Fig. 13-5. Another method of holding the gouge.

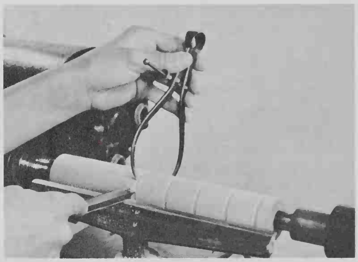


Fig. 13-6. Laying out diameters with parting tool and outside caliper.

Rough out the diameter of both the backing block and the stock for the finished turning. Check their surfaces to see that they are flat and will fit together smoothly. Spread glue on the surface of each piece, place a sheet of paper in the joint and clamp them together. Allow the glue to harden overnight, then mount the work on a faceplate, Fig. 13-7. Screw the faceplate on the lathe spindle and turn the work.

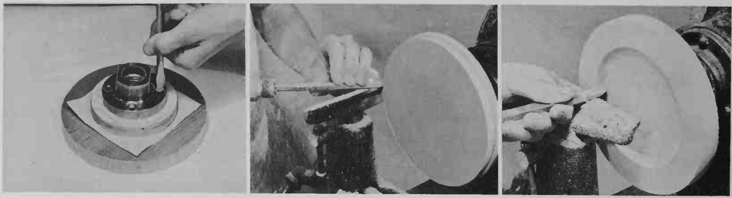


Fig. 13-7. Faceplate turning. Left. Mounting stock on faceplate. Center. Truing edge with a spear point. Right. Using a round nose chisel.

After the turning is finished, use a wide wood chisel to split the glue line. Keep the faceplate mounted on the lathe and work carefully all the way around the joint with the bevel of the chisel turned toward the backing block.

FACEPLATE TURNING

All faceplate turning should be done by the scraping method with the tool rest holding the cutting tool edge on a level line through the center of the work. The spear point, round nose and skew are good tools to use. The gouge should not be used on faceplate work.

Screw the faceplate onto the lathe spindle until it is tight against the shoulder. Set the lathe on the slowest speed and true the edge with a shoulder cut, using the spear point as shown in Fig. 13-7. Position the tool rest along the face of the stock and make a light cut, working from the center toward the outside. When both the edge and face are smooth and true, you can increase the speed (if the diameter is not large) to finish the turning.

SANDING LATHE WORK

Work can be sanded while it is rotating in the lathe. Always remove the tool rest. Work that has been scraped will require a considerable amount of sanding. Fold the abrasive paper into a pad and hold it in your fingers. A strip of paper held by the ends will often work best for spindle turnings. Since you are actually sanding across the grain with the lathe turning, you should use a very fine paper to finish the work. Final sanding should be done by hand, with the lathe stopped and working in the direction of the wood grain.

SPECIAL CHUCKING AND MOUNTING

There are many ways to mount work in a lathe. Fig. 13-8 shows a ball foot being turned in a drill chuck. The stock was prepared by gluing a piece of 3/8 in. dowel into a section of 1 1/4 in. dowel. A square block of wood could be used instead of the 1 1/4 in. dowel.

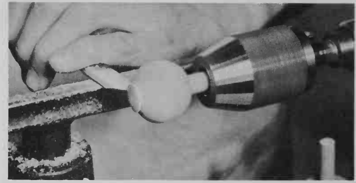


Fig. 13-8. Mounting the work in a drill chuck.

Fig. 13-9 shows the use of a "drive" chuck to mount a small part. The chuck is made by mounting a piece of hardwood on the faceplate. A 5/8 in. hole is then carefully bored through the center. Pieces of 1/2 in. square stock can be driven into the chuck. When the turning is complete, the knock-out rod (used to remove the spur center) is used to drive the piece out of the chuck.

If a drill chuck is not available to turn the ball foot, as shown in Fig. 13-8, the "drive" chuck could be used. Mount the 1/2 in. square stock, turn it to a 3/8 in. diameter, then glue on the 1 1/4 in. dowel. If the fit is tight you will need to wait only a few minutes before continuing with the work.

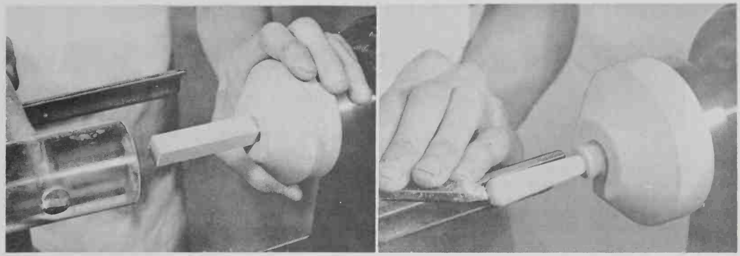


Fig. 13-9. A drive chuck. Left. Driving a 1/2 in. square into a 5/8 in. hole. Right. Turning leg for a candelabra.

Turning on a "mandrel" is shown in Fig. 13-10. Here the square stock, driven in the chuck, has been turned to a slight taper. A section of dowel with a

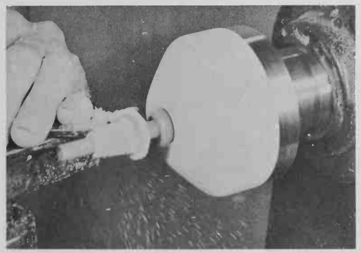


Fig. 13-10. Turning work mounted on a mandrel.

hole drilled through its center has been pressed on and is being turned. Empty thread spools can be used instead of the drilled dowels.

Small wheels for pull toys and models can be quickly mounted on the faceplate with a wood screw as shown in Fig. 13-11. The blanks are first cut out on the jig saw and then turned on the lathe; first on one side and then the other.

Small parts are fun to turn on the lathe. Always keep your tools sharp, and do a lot of shaping with coarse abrasive paper.

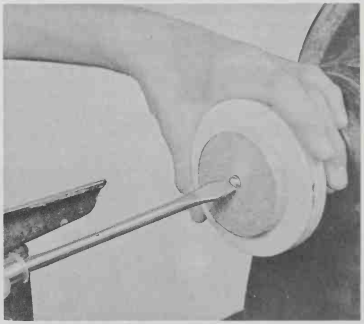


Fig.13-11. Mounting small wheel on a wood blank fastened to faceplate.

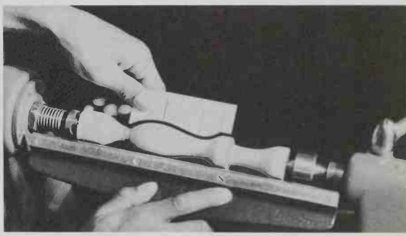
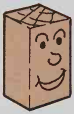


Fig. 13-12. Using a template to check contour (shape) of turning.

LATHE SAFETY RULES



WOODY SAYS:

"1. Before starting the machine, be sure that spindle work has the cup center properly imbedded, tail stock and tool rest are securely clamped, and that there is proper clearance between the rotating stock and the tool rest.

2. Before starting the machine for faceplate work, check to see that the faceplate is tight against the spindle shoulder.

3. Wear goggles or a face shield to protect your eyes.

4. Select turning speed carefully. Large diameters must be turned at the lowest speed. Always use the lowest speed to rough out work.

5. Wood with knots and splits should not be turned. Glued-up stock should cure at least overnight.

6. Keep the tool rest close to the work.

7. Remove the tool rest for sanding operations.

8. Use a scraping cut for faceplate work.

9. Remove both live and dead centers when not in use.

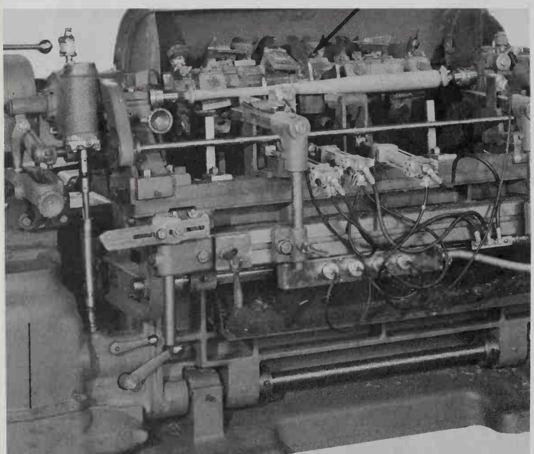
10. When you stop the lathe to check your work also check and oil the cup center.

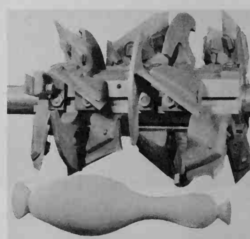
11. Keep the lathe tools sharp.

12. Do not wear loose sleeves or neckties. They are especially hazardous around a lathe."

QUIZ – UNIT 13

1. A 12 in. lathe will measure ________ in. from the bed to the center of the spindle.
2. When in use the tool rest assembly is clamped to the ________ of the lathe.
3. The spur center is mounted in the spindle of the ________ ________.
4. The turning tool that should be used for roughing out spindle work is called a ________.
5. When using round nose turning tool, beveled side should be turned ________.
6. Faceplate turning should be done by the ________ ________ method.
7. A piece of paper should be placed in the glue line when mounting turning stock on a ________.
8. When roughing out spindle work, the tool should be moved from ________ to
9. When turning the face surface of faceplate work, it is best to move the tool from the ________ toward the ________.
10. When sanding work on the lathe, the ________ ________ should be removed.





Left. Automatic lathe set up to produce baseball bats. Stock (mounted between centers) revolves about 25 rpm as it is moved back into the large cutterhead assembly (arrow). The cutterhead revolves at a high speed – forming the bat in just a few seconds. Above. Close-up view of cutterhead "makeup" for producing bowling pins.
(Mattison Machine Works)

Unit 14

WOOD, LUMBER, FOREST PRODUCTS

After studying this unit, you will know:
1. **The structure of wood and how it grows.**
2. **How wood shrinks when it is dried.**
3. **How trees are made into lumber.**
4. **How plywood, hardboard, and particleboard are manufactured.**

WOOD STRUCTURE AND GROWTH

The basic structure of wood consists of long narrow tubes or cells (called fibers or tracheids) no larger around than a human hair. Their length varies from about 1/25 in. in hardwoods to about 1/4 in. in softwoods. The cell walls are composed of tiny strands of cellulose. The structure also includes cells that run in a direction from the pith to the bark and form the wood rays. All of these cells or fibers vary in size and shape and are held together with a substance called lignin.

New cells are formed in the cambium layer that is located just under the bark of the tree. The inside of this layer develops new wood cells and the outside develops new bark. The growth in the cambium layer takes place during the spring and summer and forms separate layers each year. These layers are called annular rings. See Figs. 14-1 and 14-2.

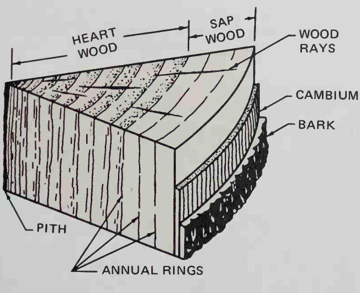


Fig. 14-1. Parts of a tree trunk.

In the spring trees grow rapidly and the cells produced are large and thin walled. As the growth of the tree slows down during the summer months the cells produced are thick walled, dense and appear darker in color. These annular growth rings form the wood grain patterns that are seen on the surface of boards cut from the tree.

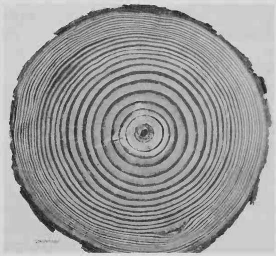


Fig. 14-2. Section of log showing annular rings. (Forest Products Laboratory)

The sapwood contains living cells and may be several inches or more in thickness. Faster growing trees usually have a thicker layer of sapwood. The heartwood of the tree is formed as the sapwood cells become inactive. It usually has a darker color because of the presence of gums and resins.

MOISTURE CONTENT AND SHRINKAGE

Before wood can be used, a large part of the moisture (sap) must be removed. When a living tree is cut, more than half of its weight may be moisture. The heartwood of a "green" birch tree has a moisture

content of about 75 percent. Most cabinet and furniture woods are dried to a moisture content of 6 to 10 percent.

The amount of moisture in wood is expressed as a percent of the oven-dry weight of the wood. For example; a piece of wood that weight 12 lbs. was completely dried in an oven and was then found to weigh 10 lbs. The amount of moisture in the original piece was 2 lbs. or 20 percent of the oven-dry weight.

Moisture in wood is contained in the cell cavities and in the cell walls. As lumber dries, the moisture first leaves the cell cavities. When the cells are empty but the cell walls are still full of moisture, the wood has reached a condition called the fiber saturation point. This is at about 30 percent moisture content for all kinds of wood.

Wood does not start to shrink until after the fiber saturation point has been reached. If dried to a 15 percent moisture content, it will have been reduced by about one half of the total shrinkage possible. A plain sawn birch board that was 12 in. wide at 30 percent moisture content will measure only about 11 in. at 0 percent moisture content. Wood shrinks most along the direction of the annular rings and a little less across these rings. There is practically no shrinkage in the length. How this shrinkage affects lumber cut from a log is shown in Fig. 14-3. As moisture is added to wood, it swells in the same proportion that the shrinkage has taken place.

A piece of wood will give off or take on moisture from the air around it until the moisture in the wood is balanced with that in the air. At this point the wood is said to be at equilibrium moisture content (E.M.C.). Since wood is exposed to daily and seasonal changes in the relative humidity of the air, it is continually making slight changes in its moisture content and, therefore, changes in its dimensions. This is the reason doors and drawers often stick during humid summer months but work freely the rest of the year.

Moisture change in wood takes place slowly under normal conditions. Paint and other finishes will slow the action still more but will not entirely prevent it. An article should be made of wood that has a moisture content very close to the E.M.C. it will attain in service. Try to design your projects so that the shrinking and swelling of the wood will not affect the structure.

LUMBERING

The method and equipment used in lumbering vary according to the geographic location and the size of the operation. In general, however, lumbering includes selecting and cutting the trees, Fig. 14-4, transporting the logs to the sawmill, sawing the logs into lumber and drying and planing the lumber.

The lumbering industry moved across the continent with the pioneers. It has grown with the nation and today is our fifth largest industry. There are many sawmills, some in every state, that provide lumber to about 4,000 wholesalers, who, in turn, supply some 30,000 retail lumber yards. The development of heavy machines and equipment, plus continued improvement in methods and procedures, has resulted in a high level of efficiency. Today, for the nation as a whole, it takes only about 28 man-hours to log, manufacture and distribute to the consumer a thousand board feet of lumber.

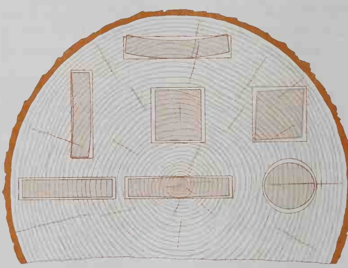


Fig. 14-3. How wood shrinks. (Forest Products Laboratory)

Our forests are one of our greatest national resources. The trees that supply lumber and other forest products are a "crop" that can be grown over and over again on the same land. Through sound management under the American Tree Farm System millions of acres of woodlands are being protected and managed so that our wood supply can last indefinitely. About 42 percent of our lumber comes from industry owned lands. Privately owned land, including farm wood lots, provide about 48 percent, with the remaining 10 percent coming from land owned by the government.

Today scientific studies are used to select the timber and method of cutting. After the tree is cut down and trimmed, it is cut into suitable lengths. The logs are then skidded to a central point, where they are loaded on trucks or railroad cars for the trip to the sawmill. In a few areas, logs are floated down rivers or streams to the mill. At the sawmill the logs are usually stored in ponds, Fig. 14-5, until they can be sawed. The water makes it easy to move and sort the logs and prevents end checking. Some hardwood logs are too heavy to float very well, and are stacked in the mill yard where they are sprayed with water to keep them from drying out.

In large mills, logs are pulled up a "jack ladder" to the sawing deck where they are washed and the bark is removed, Fig. 14-6. The log is then placed on the carriage of the "headrig" and moved through a giant band saw that cuts the log into boards and timbers, Fig. 14-7.

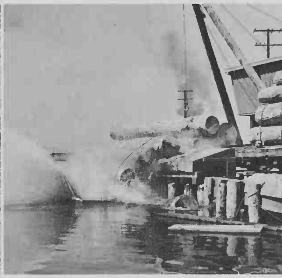
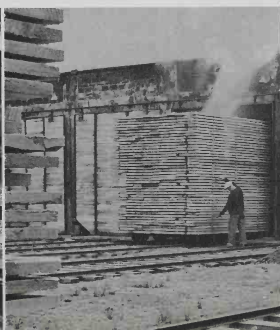
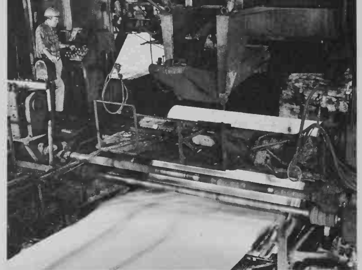


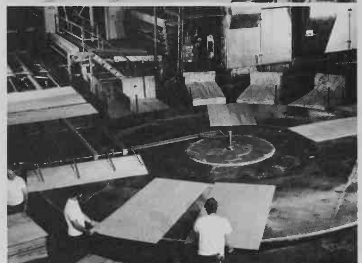
Fig. 14-4. Left. Power chain saw bites through tree 10 times faster than hand operated saw. Fig. 14-5. Center. Logs arriving at mill are stored in pond. Fig. 15-6. Right. Stream of water of a pressure of 1350 pounds per square inch removes bark from log. (Weyehaeuser Co.)

From the headrig the boards move to smaller edger and trimmer saws that cut them to proper widths and lengths. The boards are then sorted, graded and stacked either in open sheds for air drying, or in huge ovens for kiln drying, Fig. 14-8. Large mills have a planing mill section where the dried lumber is surfaced and made into finished lumber, Fig. 14-9.

Fig. 14-7. Left. Headrig rips log into boards. Band saw blade (see arrow) is over 60 ft. long. Fig. 14-8. Center. Moving wood into dry kiln. Notice "stickers" that separate the layers so air can move around each piece. Fig. 14-9. Right. Planing lumber to specified dimensions. Two inch lumber can be S4S at the rate of 600 linear feet per minute.
(American Forest Prod. Ind.) (Forest Products Lab.) (Weyerhaeuser Co.)







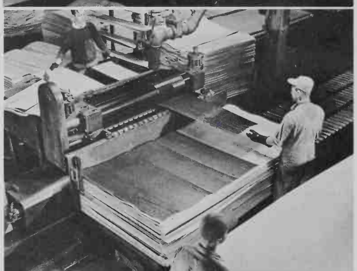


Fig. 14-10. Top. Rotary cutting veneer. Fig. 14-11. Center. Veneer sheets move from dryer to revolving table for sorting. Fig. 14-12. Bottom. Applying glue and stacking veneer sheets. (American Plywood Assoc.)

PLYWOOD

Many top-quality logs are made into plywood. The veneer is produced either by sawing, slicing or rotary cutting, Fig. 14-10. In rotary cutting, the most common method, the logs are mounted in a large lathe and are rotated against a razor-sharp knife that peels off a thin continuous sheet of wood. The long sheet of veneer is cut into specific widths and is then run through a dryer, Fig. 14-11, to remove the moisture.

The sheets are carefully sorted and matched so that the best veneers will be on the outside of the plywood. They are then coated with glue, Fig. 14-12, and stacked so that the grain of each sheet is at a right angle to that of the next. The stacks are placed in powerful presses that exert a pressure of more than 150 lbs. per square inch. The plates of the press are heated to speed the setting of the glue. After the panels leave the presses, they are sanded and trimmed to size.

HARDBOARD

Hardboard is a manufactured product made from wood fibers. The fibers can be secured from any kind of wood. Shavings and small pieces (formerly considered to be waste material) are often utilized.

The wood is first reduced to individual fibers, either by a steam process or mechanical grinding. The fibers are thoroughly washed, Fig. 14-15. They are then mixed with water and fed onto a moving screen. The water runs through the screen and a thick blanket of fibers is formed, Fig. 14-16.

The blanket is pressed between rollers and cut into sheets. These sheets are then placed in giant hot presses where the lignin (natural adhesive in wood) bonds the fibers together into hard, stiff boards.

Hardboard panels are usually 1/8, 3/16 and 1/4 in. thick. Various textures can be molded into the surface or designs can be cut through the material. Hardboard is often finished with a printed wood grain pattern, Fig. 14-17. Panels with this type of finish are widely used for wall paneling and furniture construction.

PARTICLEBOARD

Particleboard is made from wood flakes and chips, bonded together with an adhesive. The manufacturing process includes many of the same operations used to make hardboard, Fig. 14-18. Particleboard is not as dense (heavy) as hardboard. After the panels are formed the surfaces are usually sanded.

Particleboard can be made with different sizes of chips. Large chips are generally used in the center to provide strength and fine ones at the surface to provide smoothness. Thicknesses may range from 1/4 to over 1 inch.

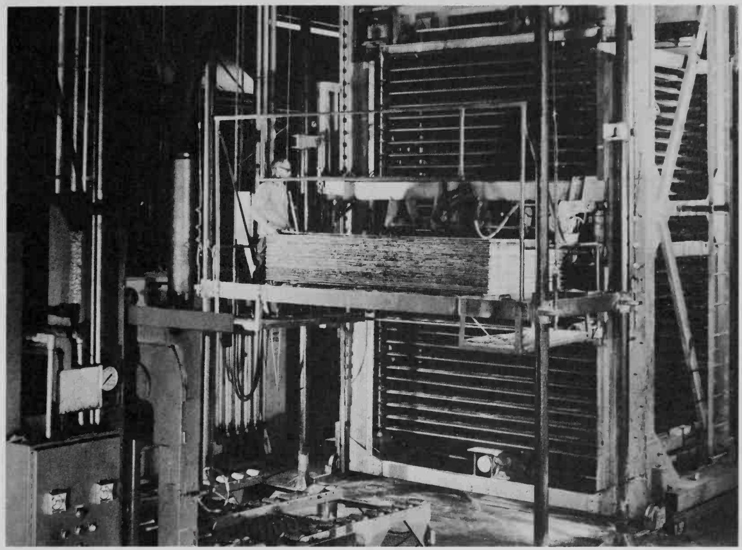


Fig. 14-13. After the veneers are laid up, they are placed between platens (steel plates) of a giant press. Pressure and heat are then applied and the veneers are bonded together, forming plywood panels. (American Plywood Assoc.)

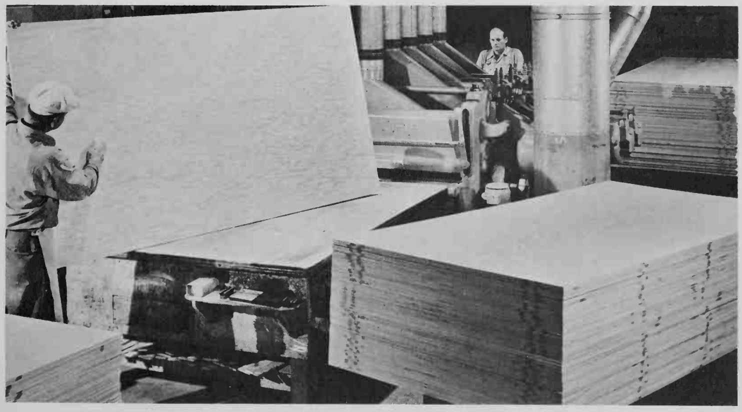


Fig. 14-14. Plywood panels are run through giant power sanders as a final operation in making "wood-and-glue sandwiches" ready for the market. (American Plywood Assoc.)

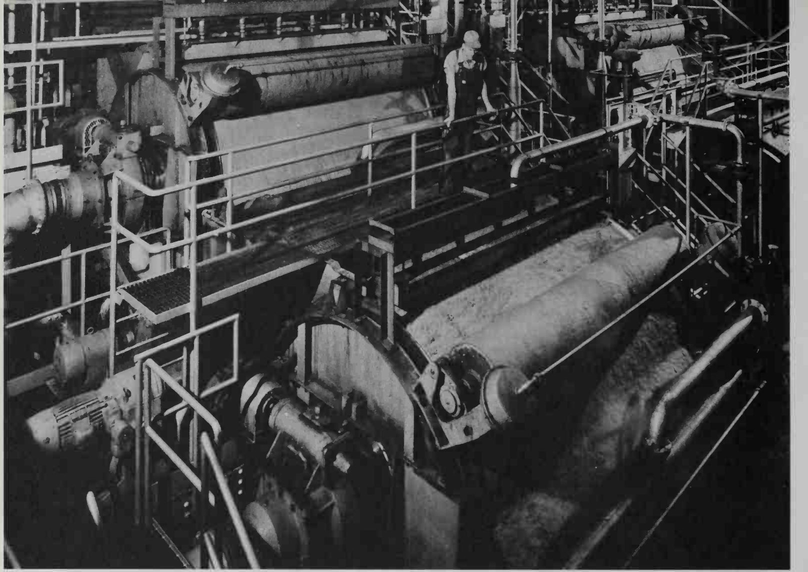


Fig. 14-15. Giant washing machines clean wood fiber stock that will be used to make hardboard. (Masonite Corp.)

Today, particleboard panels are often used as a substitute for plywood. It is satisfactory for all kinds of unexposed (inside) construction in furniture making and cabinetwork. Some plywood panels have a particleboard core (center). Particleboard is a good material to use for table and counter tops when the surface is covered with a plastic laminate. It can be worked with regular woodworking tools.

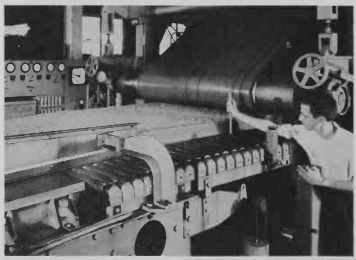


Fig. 14-16. Technician checks thickness of wood fiber blanket (machine has been stopped). This four inch blanket will be compressed into a hardboard panel 1/4 in. thick. (Masonite Corp.)

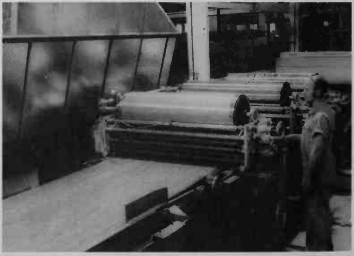


Fig. 14-17. Modern graining machine (off-set process) prints wood-grain pattern on hardboard panels. Each set of rollers apply a slightly different color — producing an appearance very similar to real wood. (International Paper Co.)

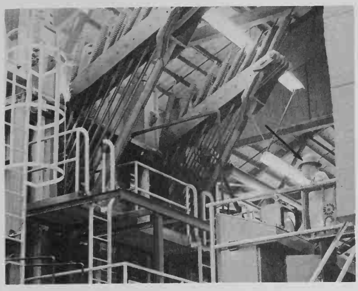


Fig. 14-18. Particleboard is bonded into panels in this giant multi-platen (plate) press. All mechanisms are controlled by a single operator (arrow) stationed at a console. (Georgia-Pacific Corp.)

HOW WE USE LUMBER

Lumber production in the United States increases each year. The Department of Commerce predicts that the demand for wood products will double by the year 2000. Our current annual production of forest products requires about 12 billion cubic feet of wood.

Most of our lumber is used to build homes, public and commercial buildings and other large frame structures. Four out five of our homes are built with wood frames, Fig. 14-19. Wood is used for outside and inside finish. The soft, warm tones, and interesting textures and grain patterns make it an ideal material for doors, casings, cabinets and built-in fixtures. Wood is easy to cut and shape and lasts a long time.

Fig. 14-19. Most of the lumber used in this country goes into the construction of homes and industrial buildings. (Weyerhaeuser Co.)

Most hardwood lumber goes to industrial plants that produce furniture, case and cabinet work, boats, parts for machinery, athletic equipment and many other articles that make our work easier and our lives more enjoyable.

One of many new developments that extends the use we make of lumber is the prefabrication of trusses, arches and other structural units by glued lamination. Lamination of wood, coupled with specially designed metal connectors, has become an important element in both light and heavy construction.

OTHER PRODUCTS OF THE FOREST

Wood is about 50 percent pure cellulose, and through the magic of modern chemistry it can be made into thousands of products. Some of the more important ones are paints and lacquers, photographic film, cellophane, rayon, plastics, linoleum, alcohol and resins.

Each year more than 15 million cords of pulp wood and tremendous amounts of wood residue (waste) are used for paper and cardboard. Books, newspapers, magazines, packages for food products, shipping boxes and countless other items are products of our forests.

QUIZ – UNIT 14

1. Wood cells or fibers are held together with a substance called __________.
2. Wood cells are formed in a layer under the bark called __________.
3. After a tree is cut down its age can be determined by counting the __________ __________.
4. If a piece of wood that weighed 55 grams was thoroughly oven-dried and then found to weigh 50 grams, the moisture content would have been __________ percent.
5. The fiber saturation point for all kinds of wood is about __________ percent moisture content.
6. The abbreviation E.M.C. stands for __________________.
7. Today, with modern methods and equipment, it takes about __________ man-hours to produce a thousand board feet of lumber.
8. The two methods of drying lumber are air drying and __________ drying.
9. The most common method of cutting veneer is the __________ method.
10. Plywood panels are formed in giant presses that apply both __________ and pressure.

Fig. 14-20. Central control panel for a modern papermaking machine. The machine is over 400 ft. long. The paper mat is formed through a process similar to the one used to produce the hardboard blanket described on page 90. It is then dried by running it over as many as 50 heated rolls. Note the giant roll of paper being produced (arrow). (Westvaco Corp.)

Unit 15
CAREER OPPORTUNITIES

After studying this unit, you will know:
1. **What foresters do.**
2. **What lumbering and manufacturing opportunities exist.**
3. **What woodworking trades offer.**
4. **What careers are offered in wood science and research.**

Many occupations are avilable to persons who are interested in woodworking. They range from the cultivation of trees; to cutting lumber and making plywood; to fabrication of furniture and cabinetwork; to the distribution and sales of products. Employment opportunities are provided by more than 50,000 manufacturing plants, a vast distribution system, and some 75,000 builders and contractors.

FORESTRY

Careers in forestry consist of important and exciting work. Basically, they deal with the management of our forests so that the nations supply of timber will be continuous. Many specialists are needed in the areas of planting and cultivation, disease and pest control, fire protection, selection and cutting, and recreational planning. See Fig. 15-1.

Fig. 15-1. Foresters graft a scion (budded shoot) from a superior tree to a tree in a seed orchard. This is one of many steps used to develop "supertrees" that will grow nearly twice as fast as naturally grown trees. (Georgia-Pacific)

Professional foresters are trained in environmental matters. They know how to maintain a continuous supply of raw material and, at the same time protect the soil, water, air and wildlife. You can obtain booklets that tell about careers in forestry by writing to The Forest Service, U.S. Department of Agriculture, Washington, D.C., 20250.

LUMBERING

The United States produces one-third of the world's lumber, over one-half of its plywood and nearly one-half of its paper and paper board. Lumbering operations begin with the selection and cutting of trees, Fig. 15-2. After the logs arrive at the sawmill, many skilled operators and technicians are needed to change it into lumber, plywood, composition board, and many other materials. See Figs. 15-3, 15-4 and UNIT 14.

MANUFACTURING

Industrial woodworking plants convert the lumber, plywood and other basic forest products into furniture, doors, windows, and many other finished products, Fig. 15-5. Today, an increasing number of plants specialize in the manufacture of building components (units). Thus the construction industry is provided with "parts" instead of "pieces" which reduces labor costs at the building site.

Woodworking plants provide employment for unskilled and semiskilled workers, where only a few weeks of training is required. These jobs include

Fig. 15-2. Here is an exciting job – felling (cutting) trees. One logger makes the backcut with a modern chain saw. The other logger drives a steel wedge into the kerf to relieve pressure on the saw chain. (Weyerhaeuser Co.)

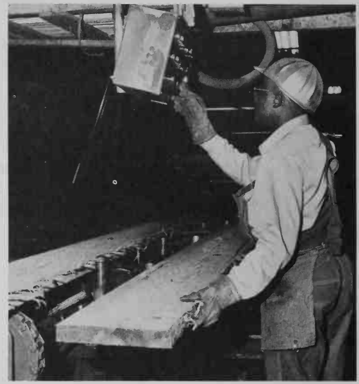
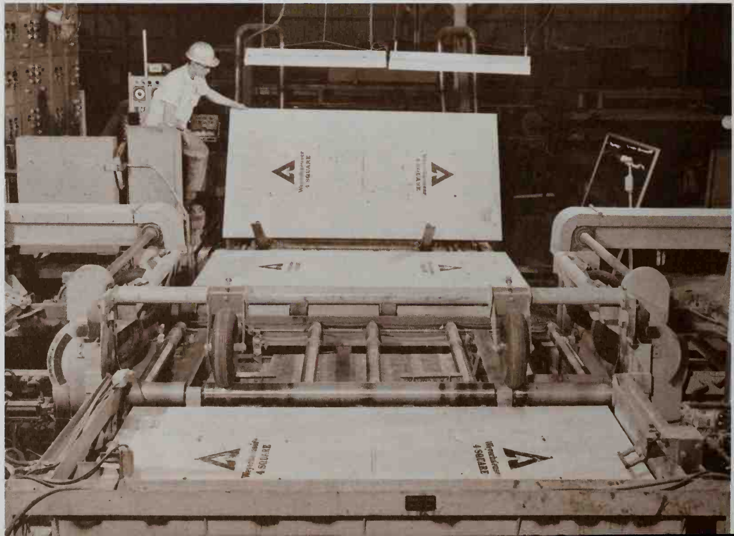


Fig. 15-3. Skilled workman operates control panel of conveyor lines in a modern sawmill. These conveyor lines move rough sawn boards from headrig to edger and trimmer saws. (International Paper Co.)

Fig. 15-4. Technician performs final inspection of plywood. Conveyor line mechanism turns panel over so both sides can be checked. Panels are then automatically stacked by equipment shown in foreground.



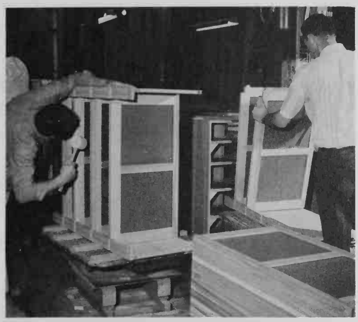


Fig. 15-5. Basic assembly of chest of drawers in a furniture factory. The units are then placed on a conveyor line that carries them through additional assembly operations and finishing. (Thomasville Furniture Ind. Inc.)

Fig. 15-6. Multiple screw driving machine attaches hardware to window jamb. Screws are automatically fed from hoppers (arrow). (Caradco)

feeding machines and handling material, Fig. 15-6. The increasing use of automatic equipment is reducing the need for unskilled workers.

More important job opportunities consist of setting up machines, grinding cutter knives, and checking adjustments during production. These jobs require skilled craftsmen with lots of experience. Technical training is required to qualify for the work of building machine fixtures, organizing production lines, and directing the production schedule.

Other woodworking occupations include boatbuilding, wood finishing and patternmaking. The latter consists of making the wooden models used in metal casting. Most of the workers in these areas must be highly skilled. Technical training (secured in school or on the job) will usually result in rapid advancement.

CONSTRUCTION

Experts predict that the construction industry will grow very rapidly in the next few years, and will continue to require a higher proportion of skilled workers than any of the manufacturing industries.

Approximately one-third of all building construction craftsmen are carpenters – the largest single skilled occupation. Carpenters are key workers on the construction site and must know the where, when and how of nearly every kind of building material. Their work includes many types of construction – residential (homes), commercial, industrial and institutional buildings.

The carpenter must be highly skilled in the use of tools and machines. Many of the hand tools are just like the ones you have learned about in the school shop. See Fig. 15-7.

To become a skilled carpenter (called a "journeyman"), you need to complete high school or technical school courses. Then, you must serve as an apprentice for a number of years, learning information and skills on the job. An apprentice receives wages ranging from 50 to 90 percent of a journeyman carpenter.

A career as a carpenter is hard work, but it also is profitable and interesting. Carpenters experience a special feeling of satisfaction at the end of each day or week – as they see the results of their efforts.

DISTRIBUTION

Many career opportunities exist in the distribution and sale of lumber and wood products. There are over 30,000 retail building supply centers in the nation. To find employment in these centers you must have a good understanding of wood and building materials. You must be able to read blueprints, prepare estimates and figure building costs. It will also be helpful

Fig. 15-7. Carpenter hanging (installing) an interior door. Note the spiral ratchet screwdriver he is using to attach a hinge. (Stanley Tools)

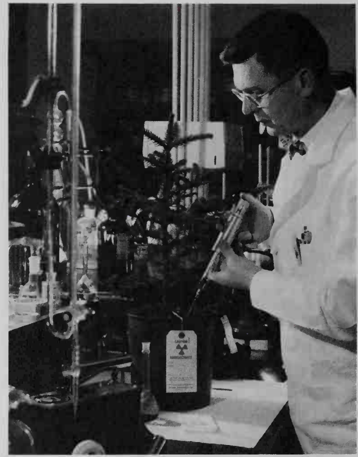


Fig. 15-8. Wood scientist injects radioactive isotopes into growing container. A radiation counter is then used to detect the movement of nutritional elements within the tree – one small part of the search for ways to grow better trees faster. (Weyerhaeuser Co.)

if you have a general knowledge of application procedures (how materials are put together).

Managers and salesmen in furniture stores should be able to identify various kinds of wood. They also need to know about wood joints, types of construction, and kinds and qualities of wood finishes.

WOOD SCIENCE AND TECHNOLOGY

Industrial companies and government agencies offer attractive career opportunities to wood scientists and technologists. Each day the search continues for better methods of growing trees; ways to make greater use of wood waste; and more efficient manufacturing processes. See Fig. 15-8. Wood scientists need a high level of technical knowledge. This is also true for those who design and build woodworking machines, compound adhesives and develop new wood finishes.

College and university degrees are generally required for those who work in forestry, forest product research, and furniture and cabinet design. More than 40 schools located throughout the nation provide training in this field of study.

If you have ability in woodwork and enjoy working with young people, the teaching profession can offer you a rewarding career. Over 200 educational institutions (some in every state) offer teaching degrees in Industrial Arts and Technical subjects. Ask your instructor about opportunities in teaching as well as those in the various areas of woodworking.

For information about careers in woodworking, write to:

Director
Wood Industry Careers Program
National Forest Products Association
1619 Massachusetts Avenue
Washington D.C. 20036

Unit 16

WOODWORKING PROJECTS

After studying this unit, you will know:

1. **How project drawings are made.**
2. **How to follow a plan of procedure.**
3. **Which projects you want to build.**

On the following pages you will find a number of projects that you may want to build. Complete plans are provided for many of the projects. Even though you do not build these particular projects, you will benefit from a study of them. They show you how drawings are made and how plans of procedure and bills of material are set up.

Another group provides a working drawing. You will need to prepare the plan of procedure and bill of material. Some helpful suggestions concerning the procedure are given.

One group shows a picture along with a brief written description. You will need to develop all the planning materials.

Your work in the shop will not be limited to these projects and they are presented only as examples of what can be done. You will find many other good ideas for projects in magazines and catalogs and in stores and homes.

TRINKET BOX

The handy little box, Fig. 16-1, can be used to hold all kinds of small items. Its construction involves some important hand tool and gluing operations which can be applied to numerous other projects.

You can be sure of having good joints if you make and use the jigs and setups shown in the instructional pictures on rabbet joints and grooves.

After the basic box is built, you may want to apply your own ideas to the design. The corners could be chamfered or rounded and other curves cut along the bottom edge. Small blocks or turnings can be attached to the bottom for feet. You might want to add a simple carving, inlay or overlay to the top.

The inside of the box can be lined with felt or divided into compartments. To use a felt or fabric lining, first cut pieces of cardboard slightly smaller than the inside surfaces. Attach the material by cutting it larger than the cardboard, and then turning it over the edges and gluing it to the back side. The covered pieces of cardboard are then glued in place. If you line the box you may want to use hinges to attach the top.

PLAN OF PROCEDURE FOR TRINKET BOX

(See Figs. 16-1, 16-2 and 16-3)

1. Make a stock-cutting list.
2. Select the material and rough it out.
3. Plane one side of the stock for the inside surface.
4. Plane the stock for the sides and ends to finished width.
5. Cut the sides and ends to finished length.
6. Square the bottom to finished size.
7. Cut the groove for the bottom, in the sides and ends. (If this operation is performed on the power saw, it should be done while the stock is in one piece.)
8. Cut the rabbet joints in the sides.
9. Make a trial assembly of the sides, ends and bottom. Trim and fit the joints as required.
10. Sand the inside surfaces of the sides and ends and both surfaces of the bottom.
11. Glue up the bottom, sides and ends.
12. Fit the top to the sides and ends.
13. Sand the inside surface of the top and glue it in place.
14. Plane all outside surfaces.

Fig. 16-1. Trinket box you can make.

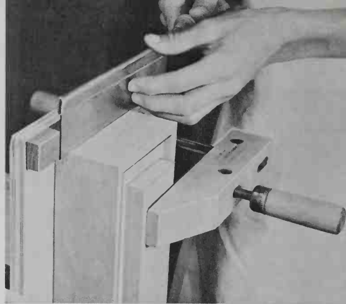


Fig. 16-3. Using a jig as a guide to cut the box open. Similar cuts are made on all four sides.

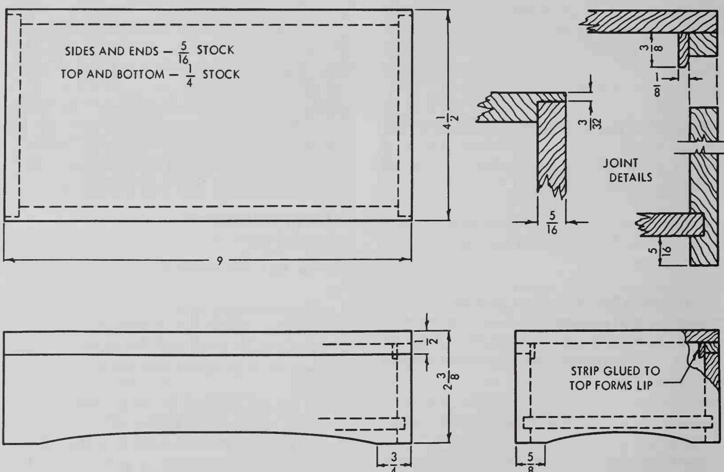


Fig. 16-2. Trinket box, working drawing.

15. Cut off the lid and plane and sand the edge.
16. Cut, fit and glue in the strip that forms the lip.
17. Cut and sand the contours on the bottom edges.
18. Prepare all surfaces for finish.
19. Seal all surfaces and sand down.
20. Apply two coats of varnish to outside surfaces. Sand between coats.
21. Polish and wax.

BILL OF MATERIAL FOR THE TRINKET BOX

NO.	SIZE	KIND	PART
1 pc.	1/4 x 4 1/4 x 9	Basswood	Top
1 pc.	1/4 x 4 3/16 x 8 11/16	Basswood	Bottom
2 pcs.	5/16 x 2 3/8 x 9	Basswood	Sides
2 pcs.	5/16 x 2 3/8 x 4 5/16	Basswood	Ends
1 pc.	1/8 x 3/8 x 26	Basswood	Lip

Finish as required

BOOKRACK

A bookrack, as shown in Fig. 16-4 or Fig. 16-5, will be a good one to have on your desk at home. Since it is so easy to remove or replace a book with this type of rack, it should be reserved for books that are used a great deal. Select a kind of wood and finish that will go with the other room furnishings.

If this is your first experience in woodwork, it will probably be best for you to follow closely the plans and drawings. You will find a number of instructional pictures showing operations being performed on the bookrack, in the units on hand woodwork.

This type of bookrack, sometimes called a book ramp, can be made in many different ways. The experienced student may want to change the size and design. Tapering the base as well as the upright takes more work but gives a pleasing effect.

PLAN OF PROCEDURE FOR THE BOOKRACK

(See Figs. 16-4, 16-5 and 16-6)

1. Make a stock-cutting list.
2. Select and rough out the stock.

Fig. 16-4. Completed bookrack.

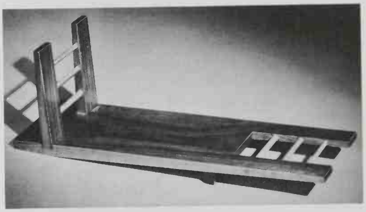


Fig. 16-5. Bookrack, alternate design.

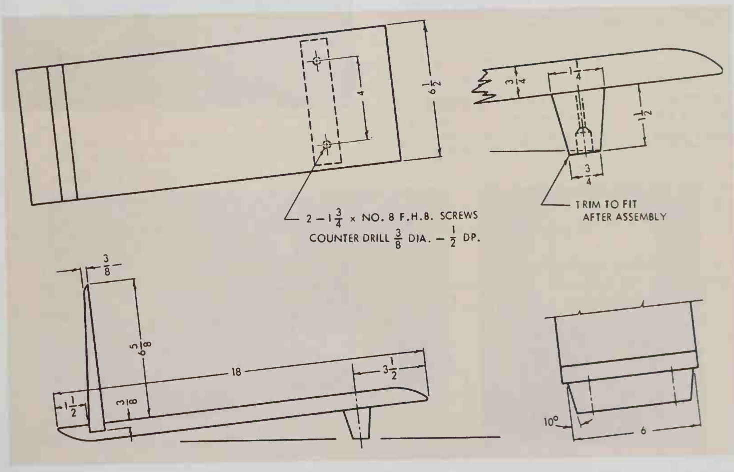


Fig. 16-6. Bookrack, working drawing.

3. Make the base and upright.
   a. Surface the stock on both faces, using a hand plane with the grain.
   b. Plane to finished width.
   c. Square off one end, lay out and plane the taper for the upright.
   d. Cut off the upright and square the base to finished length.
4. Lay out and cut the dado joint that joins the upright to the base.
5. Make the shoe.
   a. Glue up the required thickness.
   b. Plane the stock to finished thickness and width.
   c. Cut the shoe to finished length and at the required angle.
   d. Plane the angle on the sides.
6. Attach the shoe to the base.
   a. Clamp the shoe into position.
   b. Lay out and drill the screw holes.
   c. Set the screws.
   d. Plane the bottom of the shoe to fit.
7. Assemble the upright in the base and make any adjustments.
8. Disassemble the project and round the ends of the base and upright.
9. Sand all parts and prepare them for finish.
10. Glue the upright in place and attach the shoe.
11. Check all surfaces and resand if necessary.
12. Apply the wood finish.
    a. Apply paste filler, if required.
    b. Seal all surfaces.
    c. Sand the sealer coat.
    d. Apply two coats of finish. Sand lightly between coats.
    e. Polish and wax.

BILL OF MATERIAL FOR THE BOOKRACK

NO.	SIZE	KIND	PART
1 pc.	3/4 x 6 1/2 x 18	Ash	Base
1 pc.	3/4 x 6 1/2 x 7	Ash	Upright
1 pc.	1 1/4 x 1 1/2 x 6	Ash	Shoe
2 – 1 3/4 x No. 8 F.H.B. wood screws			

CUBE LAMP

For the cube lamp base, select a soft textured wood with an interesting grain pattern. The large globe-like bulb is available at most hardware or electrical stores. See Fig. 16-7.

Lay out one piece of stock that will make all four sides. Be sure to allow extra length for trimming and saw kerfs. After planing the surfaces and edges to the required size, cut the rabbet joint. You can use the rabbet plane, Fig. 4-7, page 24, or the circular saw,

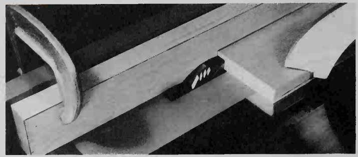


Fig. 16-8. Cutting a rabbet with the dado head.

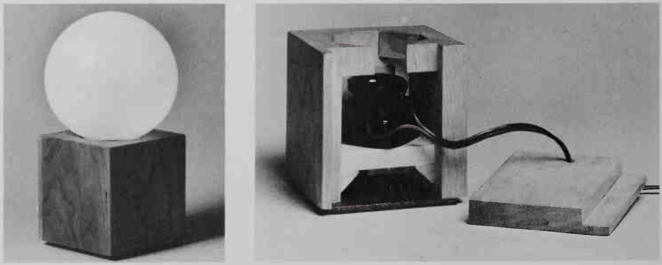


Fig. 16-7. Left. Cube lamp assembly. Right. Lamp base with side removed.

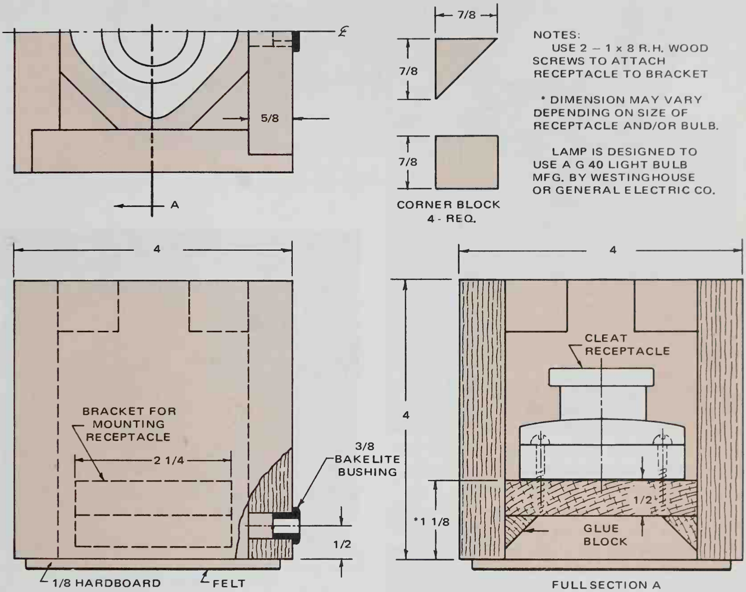


Fig. 16-9. Working drawing of cube lamp.

Fig. 12-13, page 69. If you are mass producing the lamp, a dado head setup will save time. See Fig. 16-8.

Cut the four sides to the exact length and glue them together. Install the glue blocks as a separate operation.

Fig. 16-7, Right, shows the interior assembly of the cube lamp. It will help you understand the working drawing, Fig. 16-9. Since receptacles vary in size and shape, it is best to first attach the receptacle to the bracket. Screw in the bulb, then position this assembly in the base. With the bulb in proper position, set the glue blocks.

Apply finishing coats before installing the lamp cord, bushing, switch and plug. Attach felt to the hardboard base with glue or double-faced tape.

Fig. 16-10. Cracker tray.

CRACKER TRAY

It is best to use solid stock for all the parts of this project, Fig. 16-10. The sides however, could be made from 1/4 in. plywood. Resawing nominal 1 in. stock is an economical way to produce the 5/16 in. thickness. See Fig. 12-12, page 69.

Plane a smooth surface on the stock and then cut out the various parts. Draw the half pattern for the sides and make the layout as shown in Fig. 5-4. After cutting out the top contour of the sides, the edges can be sanded as shown in Fig. 16-12.

To assemble the project, first glue and nail the sides to the ends. After the glue has set, check over this subassembly carefully and then attach it to the base. The handle is installed last.

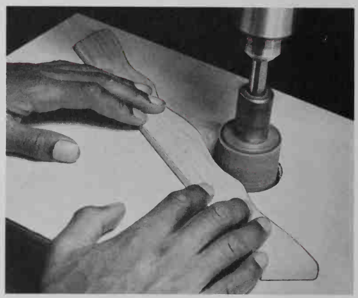


Fig. 16-12. Using a small drum sander mounted on the drill press. Be sure to use the lowest speed. An auxiliary table has been attached to the regular table.

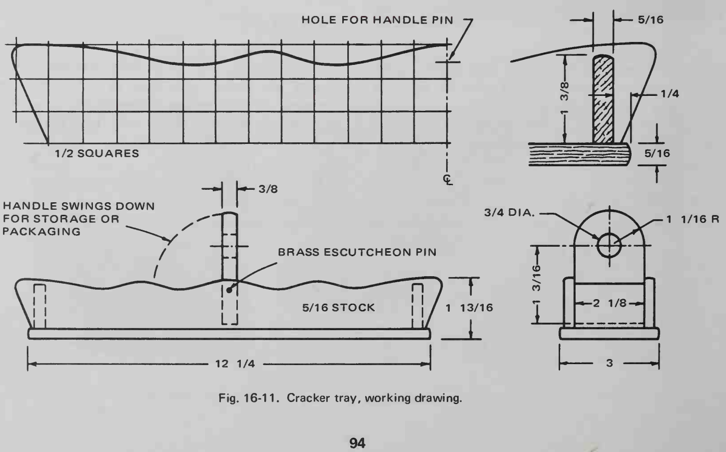


Fig. 16-11. Cracker tray, working drawing.

NAPKIN HOLDER

Cut the grooves in the base square with the surface. The slight angle (about 3 degrees) of the sides will tend to lock them in place when the parts are assembled.

When making the assembly, first insert the dowels so the sides are spaced about the same as the grooves. Apply a small amount of glue in the grooves and at the end of the dowels. Place the sides in the grooves and then force them out along the dowels with wedges. See Fig. 16-15.

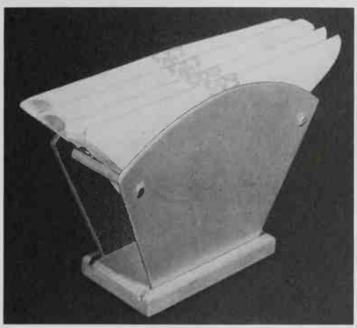


Fig. 16-13. Napkin holder.

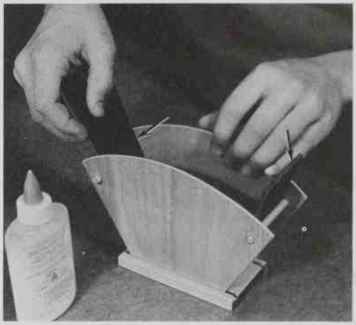


Fig. 16-15. Using hardboard wedges (arrows) to hold the sides in position until the glue sets.

If this project is mass produced, cut the base material in a long strip and then form the grooves and side chamfer before cutting to length.

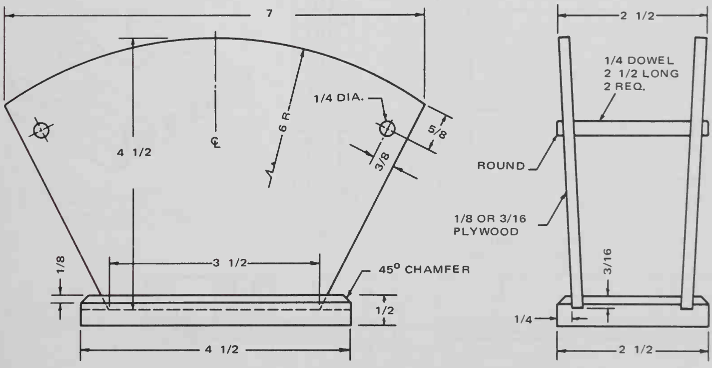


Fig. 16-14. Napkin holder, working drawing.

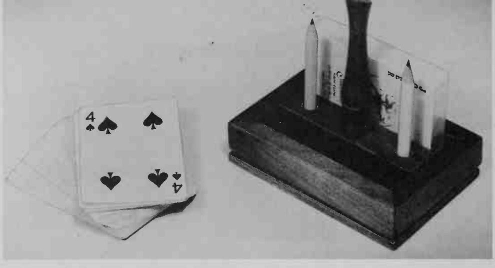


Fig. 16-16. Bridge set.

BRIDGE SET

Prepare the sides by first planing a strip of stock to exactly 1/2 x 3/4 inches. Carefully cut the miter joints, using a miter box. See Fig. 4-12, page 26. The length of the center spacer should be cut to fit after the sides have been assembled.

Assembling miter joints is a bit "tricky," so use a miter-frame clamp, Fig. 16-18, or a special gluing jig. The bottom should be cut out and attached after the upper frame unit has been completed. Turn and attach the handle as a final operation.

Assembly of the top frame can be simplified by using edge joints as shown in the working drawing.

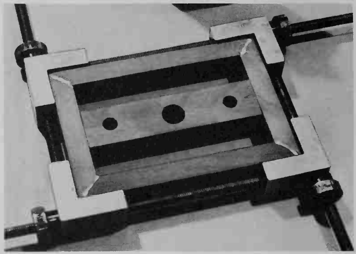


Fig. 16-18. Using a miter-frame clamp to assemble the sides and ends.

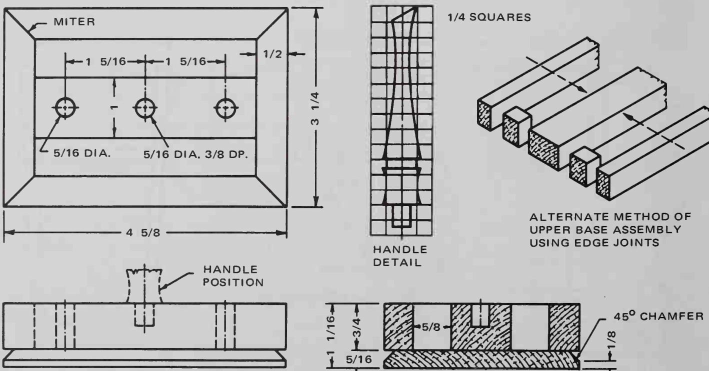


Fig. 16-17. Bridge set, working drawing.

COASTER SET

Cut square blanks for the coasters, Fig. 16-19, from stock that has been planed to 7/16 in. thick. Mark the exact center of the squares and bore a 1 in. hole — 7/32 in. deep.

Next, lay out and cut the outside contour on the jig saw. If you would prefer a beveled edge, try tilting the table, Fig. 11-8, page 61. After the coaster shapes are complete, lay out and build the rack. Glue a disk of sheet cork to the bottom of the coaster recess after the finish has been applied.

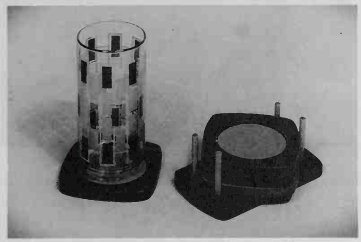


Fig. 16-19. Coaster set.

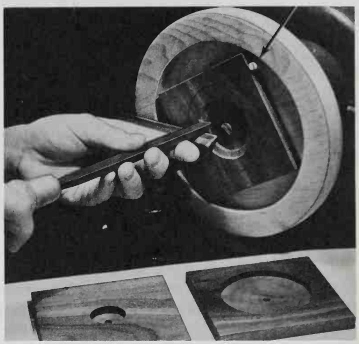


Fig. 16-21. Enlarging the coaster recess on the lathe. Note the dowel (arrow) that drives the workpiece. Keep turning speeds under 1000 rpm.

Turn a special chuck on the faceplate of the lathe as shown in Fig. 16-21. Mount the coaster blank in the chuck with a heavy gage wood screw. Use a square nose or spear point turning tool to enlarge the recess to the required diameter.

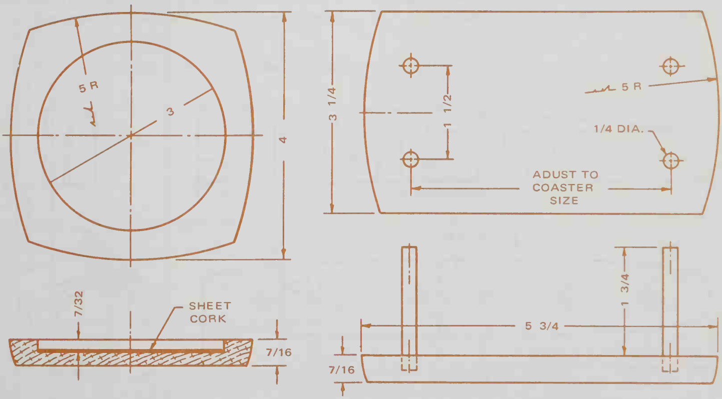


Fig. 16-20. Coaster set, working drawing.

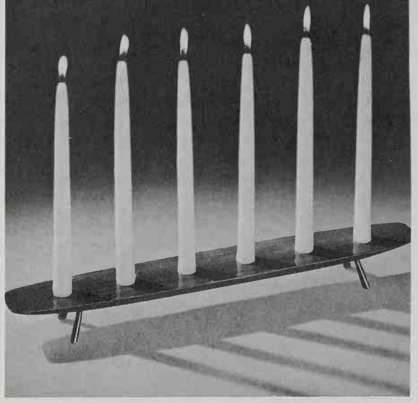


Fig. 16-22. Candelabra.

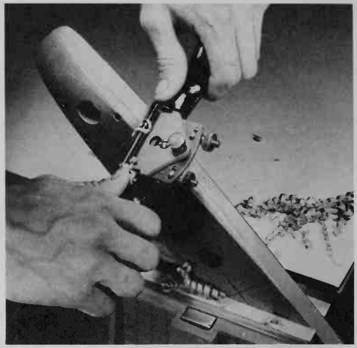


Fig. 16-24. Using a spokeshave to shape and smooth the edges and bottom.

CANDELABRA

The candelabra, Fig. 16-22, is an attractive piece for a dining or buffet setting, or for the mantle during a holiday season.

Square up the base to overall sizes and lay out and bore the holes before cutting out the contour and shaping the edges. The candelabra is shown under construction in several of the instructional pictures in the unit on drilling and boring holes. Study Fig. 6-8, page 35 before drilling holes for the legs.

The legs are turned on a lathe using the procedure shown in Fig. 13-9, page 75. If a lathe is not available, you can use wood dowels.

Give a lot of attention to shaping the curves and edges so they will be smooth and trim. See Fig. 16-24. An added touch can be gained by fitting short sections of brass tubing into the holes to hold the candles.

The attractiveness of a project like the candelabra depends a great deal on the beauty of the wood.

Fig. 16-23. Candelabra, working drawing.

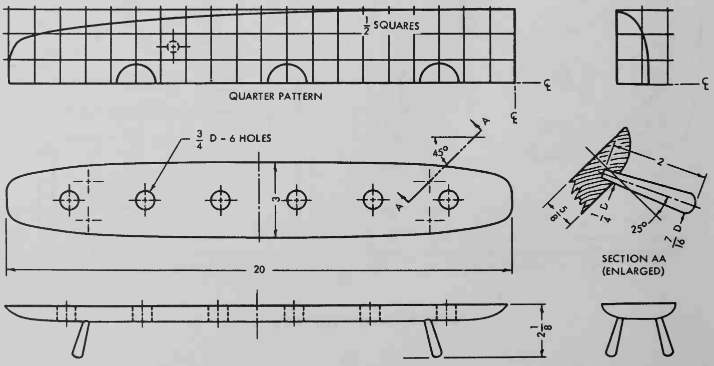


Fig. 16-25. Spoon rack.

SPOON RACK

This Early American spoon rack is designed to hold small souvenir spoons, Fig. 16-25. First develop half patterns and then lay them out on each side of a

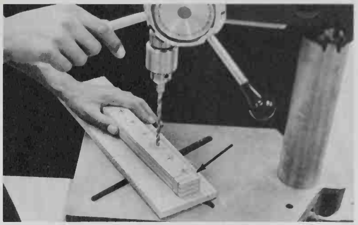


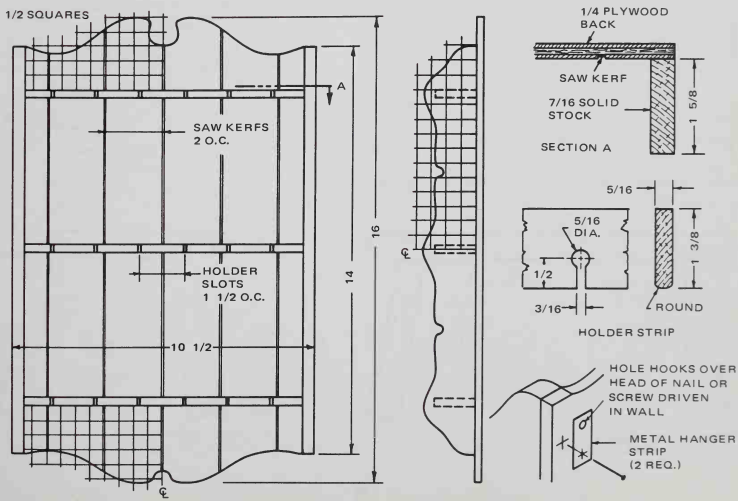
Fig. 16-27. Drilling holes in holder strips. Note tape (arrow) that holds workpieces together.

centerline and even with an edge or line, Fig. 5-4, page 28.

The three holder strips should first be squared to size and then fastened together. This will save time in drilling the holes and cutting the slots. Wrapping each end with several layers of drafting tape will usually provide enough holding power. See Fig. 16-27.

Fasten the sides to the holder strips and then mount this assembly on the back. If you plan to use a brush to apply the finish, make this final assembly after the finishing steps are complete.

Fig. 16-26. Spoon rack, working drawing.



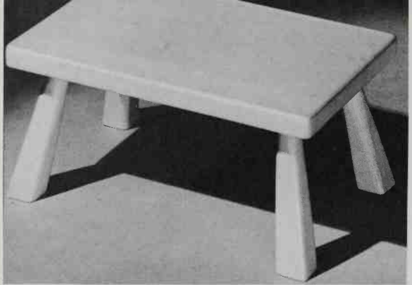


Fig. 16-28. Stool.

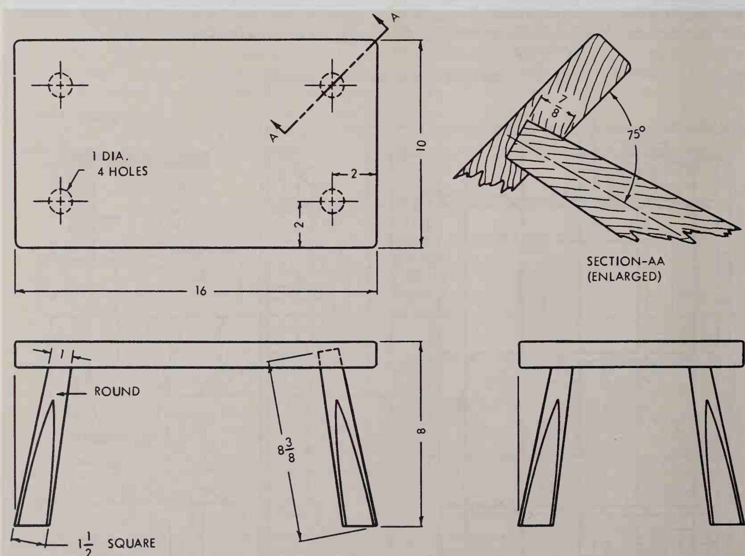
STOOL

Plane and square the top to finished size and then lay out the position of the holes. These can be bored by hand, using a jig, or a drill press can be used, as shown in Fig. 11-4, page 59.

Fig. 16-30. Sawing off legs of stool.

After the legs are glued in place they should be trimmed to the same length, then the bottoms should be cut off, so they will rest flat on the floor, Fig. 16-30. To do this, make a jig by boring a large hole in a piece of 3/8 in. stock. Clamp the jig to the bench top, set one leg of the stool in the hole and cut it off as shown in the picture. As each leg is cut off, use a block the same thickness as the jig (plus the saw kerf) to support it until all the cuts are made.

Fig. 16-29. Stool, working drawing.



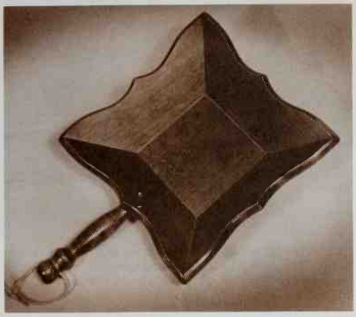


Fig. 16-31. Early American Tray.

EARLY AMERICAN TRAY

Use white pine for this attractive project, Fig. 16-31. It will be easy to work and is the kind of wood often used by Colonial craftsmen.

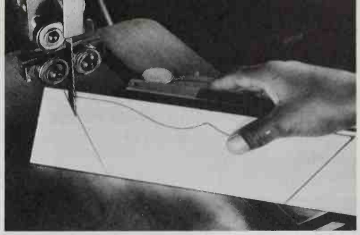
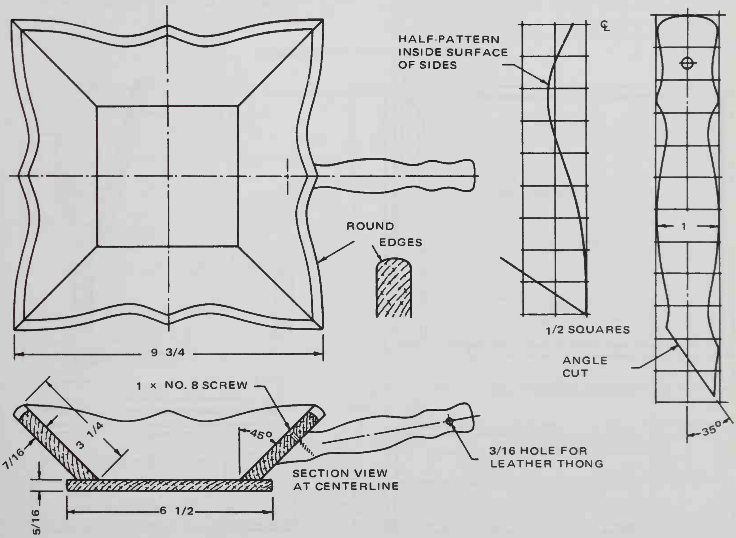


Fig. 16-33. Cutting corner joints on band saw. Workpiece is held against beveled block attached to miter gage.

After ripping and planing the strip for the sides, plane the bevel for the bottom edge. The corner joints (called compound miters) are difficult to cut. A good procedure is to first make a beveled block that will support the sides at a 45 degree angle. This block can be placed in a miter box or attached to the miter gage of the band saw. See Fig. 16-33.

Build a jig to assemble the sides. It will be easier to make the assembly with the sides in an inverted

Fig. 16-32. Early American tray, working drawing.



position. Try attaching four blocks to a flat surface so the corners will be held together. Then, by applying downward pressure with some type of clamp or a weight, the joints will be pressed together. The bottom and handle are attached in separate assembly operations.

Fig. 16-34. Letter file and easel.

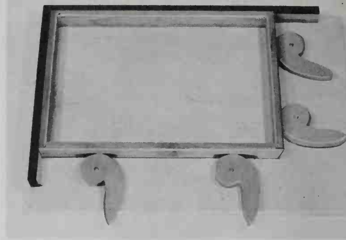


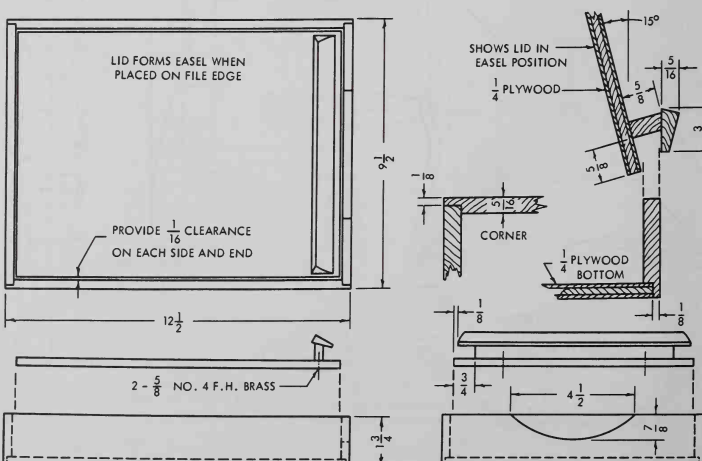
Fig. 16-36. Jig which makes it easy to glue the file box together. The eccentrics can be developed by using a string wrapped around a pencil held at the center point.

LETTER FILE AND EASEL

A letter file and easel, as shown in Fig. 16-34, serves a dual purpose. It may be used as a flat file for holding letters, bills and other papers, and can also be used as an easel to hold typing copy or a book. The picture shows how the lid and handle are placed on the sides of the box to form an easel.

Build the file box first. The rabbet for the bottom should be cut on the circular saw or with the rabbet plane while the sides and ends are in one or two long strips. They are then squared to length and the corner

Fig. 16-35. Letter file, working drawing.



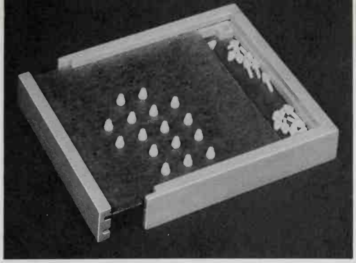


Fig. 16-37. Peg game box.

joints are cut. The rabbet for the bottom is not essential and the sides could be fitted around the bottom, using a butt joint.

PEG GAME BOX

This advanced project requires considerable skill to construct. Note how the top and one side can be pulled out to provide access to the pin storage. The adjustable friction screws hold the top in closed position.

Rip the strip of stock for the sides and plane it to exact size. Mount a single dado head blade on the table saw to cut the grooves. Use feather boards, Fig. 16-39, to insure accuracy and safety.

The rabbet joints can be cut following the procedure shown in Fig. 4-6, page 23. Prepare the hardboard panels and make a trial assembly. Glue the top to one side and the bottom to the other three sides. Make this glue-up in at least two stages — always reassembling the complete box after each application. Sand clearance in the "dry" grooves so the top will slide easily.

Install the auxiliary side, friction block and screw as final operations. A penetrating sealer is recommended for the finish.

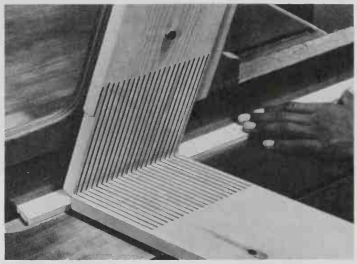
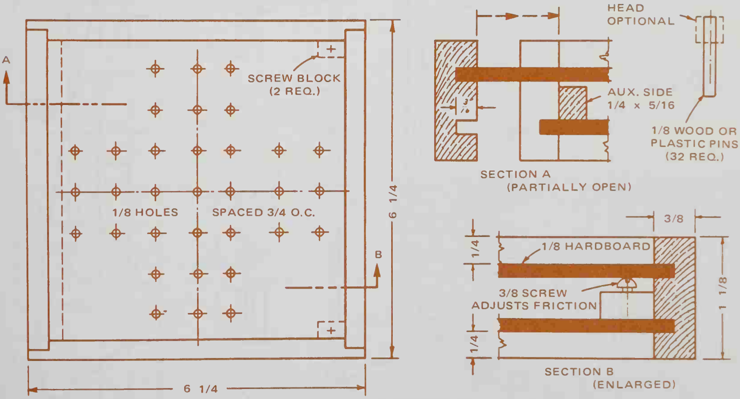


Fig. 16-39. Cutting grooves in strip that will be used for sides. Note how feather boards are used to hold the strip snuggly against the table and fence.

Fig. 16-38. Peg game box, working drawing.



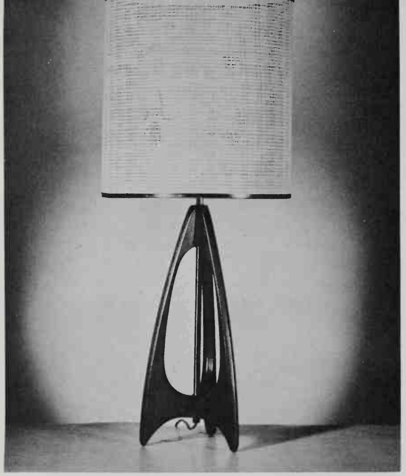


Fig. 16-40. Tripod lamp.

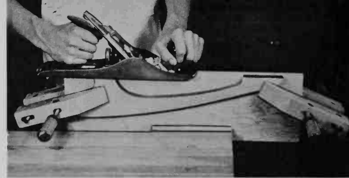
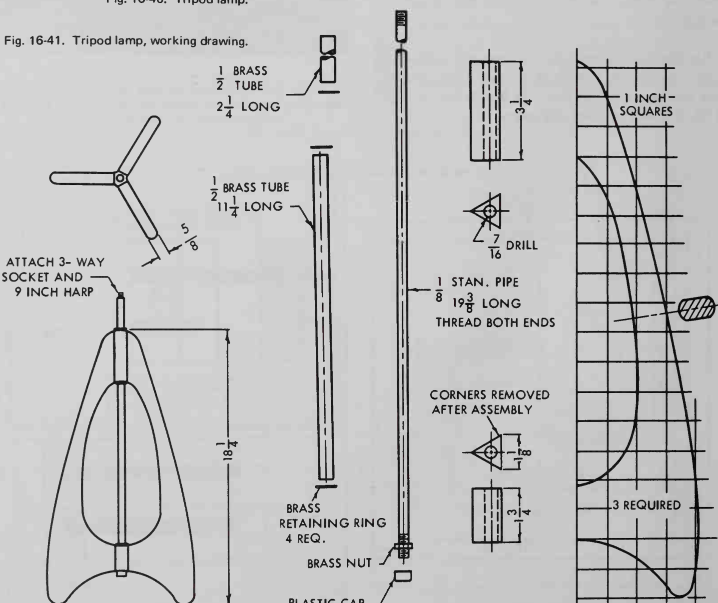


Fig. 16-42. Planing the joints with the leg clamped to a guide board.

TRIPOD LAMP

A beautiful lamp is shown in Fig. 16-40. The construction is not complicated, but it must be carefully done and finished, for when it is in use it will be well lighted and so near eye level that even slight flaws in workmanship will be quite noticeable. You should not attempt this project until you have had successful experience on several other wood projects.

Fig. 16-41. Tripod lamp, working drawing.



Select an attractive piece of wood and surface it carefully. Cut out the legs and plane the joining surfaces until they are flat and true, Fig. 16-42.

The triangular center pieces will be difficult to make by hand unless you build a jig to hold them while they are being planed, Fig. 11-3, page 59, shows a setup on the drill press that can be used to bore the holes.

Gluing the parts together will be easy if you cut out a jig like the one shown in Fig. 7-6, page 40. This holds the parts at the correct angle and also applies pressure. First, glue the triangular blocks to just one leg using the jig. After these joints have set, you can finish the gluing operation.

The shade shown in Fig. 16-40 is 14 in. in diameter and 15 in. high.

Fig. 16-43. Bookends.

BOOKENDS

Size: 3/4 x 5 x 7 3/8, Fig. 16-43.

Select an attractive kind of wood (walnut shown) and square it to size. Round the corners to a 1/2 in. radius and the edges to a 1/8 in. radius. Use sheet aluminum (1/16 x 4 1/2 x 5 1/2) for the base plate and attach it to the upright with three 3/4 in. FHB screws. Cutting a rabbet in the bottom of the upright will make a better fit.

Designs of your choice may be added. The bookends shown have overlays cut from sheet plastic. After applying finish, cover the base plates with "self-stik" flannel.

DESK PEN HOLDERS

Sizes: (left) 3/4 x 3 3/4 x 4 1/4
(center) 2 x 2 x 2
(right) 3/4 x 4 x 5 3/4, Fig. 16-44.

The holder shown on the left has a concave (dished-out) top surface about 1/4 in. deep. Form this surface with a gouge and then sand with coarse paper attached to the curved side of a rubber sanding block. See Fig. 5-9 and Fig. 9-4. Surfaces can be covered with 1/32 in. plastic laminate or left natural. Glue felt or cork disks to the bottom surface. Pen and holder units can be purchased at office supply stores and hobby shops.

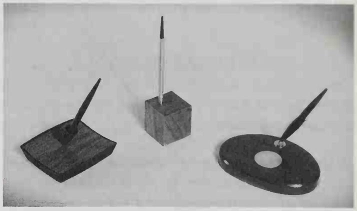
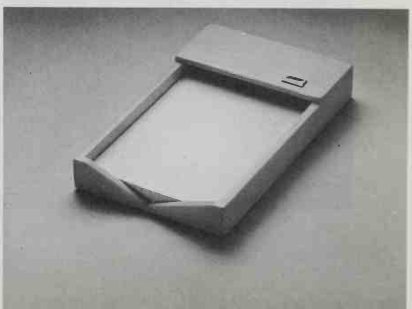


Fig. 16-44. Desk pen holders.

NOTE CARD HOLDER

Fig. 16-45 shows a note card holder made from basswood and finished with a blond stain. It is designed to hold standard 4 x 6 in. cards. The length

Fig. 16-45. Note card holder.



has been extended for better appearance and to provide space for optional mounting of pen or pencil holder.

Use 1/4 in. stock for sides and ends. Resaw thicker stock to secure this dimension as shown in Fig. 12-12, page 69. Square the bottom to size (allow 1/16 in. clearance for cards), then attach the sides and ends with glue. Use two pieces of tapered stock to form the open end.

CUTTING BOARD

Size: 1 x 5 1/4 x 7
(feet) 1 in. diameter, Fig. 16-46.

Use a close grain hardwood for this project (birch and cherry are shown). It will be best to use a water-resistant glue to assemble the strips. See Fig. 7-1, page 38. The feet are turned from dowels as shown in Fig. 13-8, page 74. Finish with a penetrating sealer.

LETTER AND KEY RACK

Overall Size: 2 1/2 x 6 1/4 x 12, Fig. 16-47.
Compartment Fronts: 5/16 x 4 x 6 1/4.

Use 7/16 in. stock for the sides. The back and compartment fronts can be made of 5/16 in. solid stock or 1/4 in. plywood. Make a sub-assembly of the back and sides. Also make sub-assemblies of the compartment fronts. The compartment front consists of a strip glued to the inside bottom edge which forms the floor. Use screws to attach the compartment fronts to the sides.

Check the fit and then disassemble for final sanding and the application of finishes.

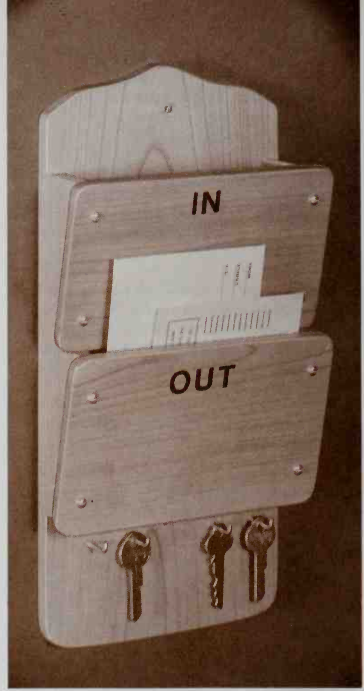


Fig. 16-47. Letter and key rack.

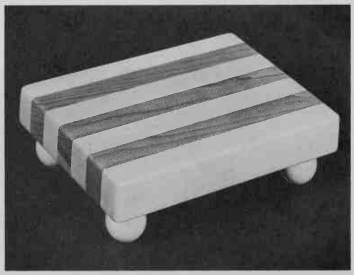


Fig. 16-46. Cutting board.

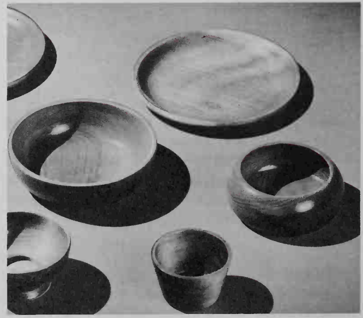


Fig. 16-48. Turned bowls and trays.

TURNED BOWLS AND TRAYS

Sizes: 2 1/2 to 7 in. diameters, Fig. 16-48.

These are all turned on a faceplate, following the procedure shown in Fig. 13-7, page 74. The thickness of stock varies from 1 to 2 in. If you plan to turn several of the same design, you should make a template to check your work.

Fig. 16-49. Salad fork and spoon.

SALAD FORK AND SPOON

Size: 2 1/2 x 10, Fig. 16-49.

The salad fork and spoon are cut from solid stock about 1 in. thick. Develop your design and then lay out the edge curve. Make the cuts on the band saw. Save the waste pieces and glue them back in place with just a few droplets of glue. Now lay out the top design and make the cuts on either the jig saw or band saw. Remove all the waste stock and form the finished shape with wood files and abrasive paper.

TWIN SERVER

Size: (base) 3/4 x 4 1/4 x 12
(feet) 3/4 in. diameter, Fig. 16-50.

Before making a working drawing of this project, secure the bowls so you will know how large to make the holes. The base is made of two layers of solid stock. The top layer is 5/16 in. thick and the bottom layer is 7/16 in. thick.

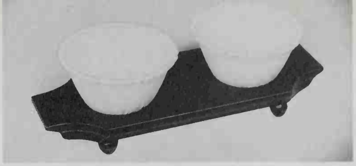


Fig. 16-50. Twin server.

Form the holes in the top layer with internal cuts on the jig saw, Fig. 11-7, page 61. Sand the edges of the holes, glue base pieces together and square up edges. Cut out corners after edges are shaped. Turn the feet on the lathe as shown in Fig. 13-8, page 74.

WREN HOUSE

Use butt joints throughout and assemble wren house with weatherproof nails. When boring the entrance hole, be sure to clamp the stock across the grain to prevent splitting.

Stock for the front and back should be 1/2 in. thick. All other parts can be made from a 3/8 in. thickness. Redwood is recommended. Do not apply any type of finish.

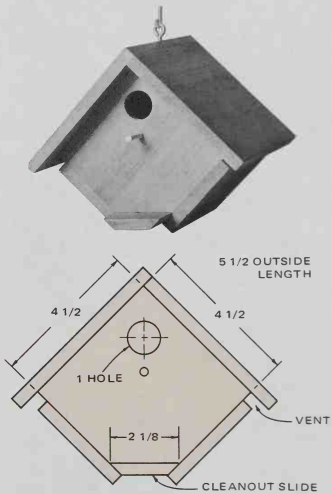
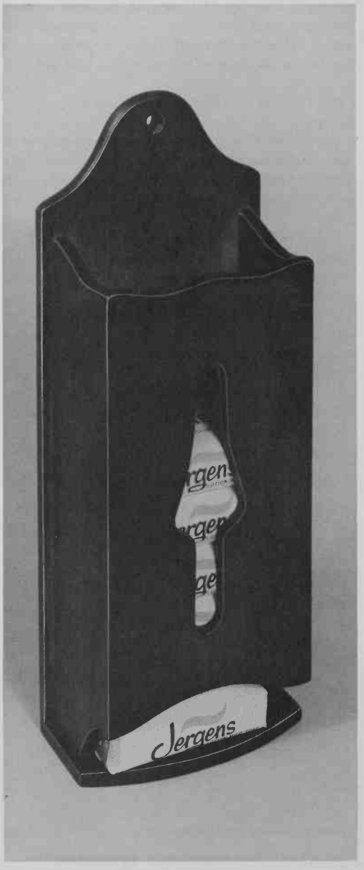


Fig. 16-51. Wren house. Drawing provides dimensions.

Fig. 16-52. Above. Tile trivet. Fig. 16-53. Below. Soap dispenser.



TILE TRIVET

Size: 6 1/2 x 6 1/2 x 1 1/4 high, Fig. 16-52.

A trivet is designed to protect table and cabinet tops from hot pans and dishes. First secure an attractive ceramic tile (6 x 6 in. size) and then build a frame in which it will fit. Use 1/4 in. plywood or hardboard for the bottom. Hold the tile in place when you glue-up the frame. The feet (as shown) are made from 3/4 in. wooden drawer pulls. You may want to turn them yourself, following the procedure shown in Fig. 13-8, page 74.

SOAP DISPENSER

Size: 2 3/4 x 4 1/2 x 12, Fig. 16-53.

This is a useful and decorative item for the bathroom. Because of the exposed edges it will be best to use 5/16 in. thick solid stock. The front panel cut out can be made on the jig saw as shown in Fig. 11-7, page 61. Edge and butt joints are used throughout.

To assemble, first make sub-assemblies of the front and sides; and the back and base. After the glue has set, these two units are fitted and assembled. Mount the dispenser firmly on the wall with two screws, one located at the top and one at the bottom.

Fig. 16-54. Desk organizer.

DESK ORGANIZER

Size: 5 1/4 x 11 wide x 11 1/2 high
(mail slots) 1 1/2 x 4 1/4, Fig. 16-54.

This cabinet of Early American design can be used on a desk or mounted on the wall. You should not attempt this project until you have had considerable experience. Although the parts are simple to cut out, the assembly requires careful work. You may want to eliminate the drawer.

Assemble the mail "pigeon holes" and two lower shelves as separate units. When complete, these units are joined to the sides. Attach the back next. The drawer is then constructed and fitted to the opening.

Fig. 16-55. Candy tray.

CANDY TRAY

Size: 3/4 x 6 1/4 x 12, Fig. 16-55.

After you have developed a pattern, lay it out on 5/8 in. stock and cut out the inside sections as shown in Fig. 11-8, page 61. Sand these edges and glue a 1/8 or 3/16 in. piece to the bottom. The outside contour is then cut and shaped. Be sure to sand the bottom and inside edges carefully before gluing, because inside corners are very difficult to work.

SOUVENIR PLATE HOLDER

Size: 5 x 7 1/2 sides, Fig. 16-56.

This project folds flat for storing or packaging. Use 1/4 in. or 5/16 in. solid stock. To save material, interlock the pattern layout as shown in Fig. 2-3, page 12. You may want to rough out each piece and fasten them together to make finish cuts, Fig. 11-7, page 61. Instead of hinges, try using small pieces of leather glued to the back edges.

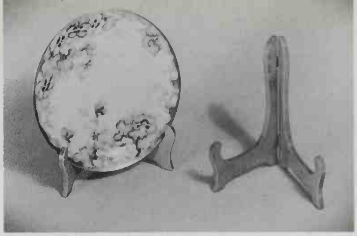


Fig. 16-56. Souvenir plate holder.

MUSICAL MANTELPIECE

Size: 3 1/4 x 5 3/4 x 10, Fig. 16-57.

The design resembles a church spire and forms an air chamber which amplifies the sound. The musical movement is mounted on the inside of the back – as high as practical. A miter joint (acute angle) should be used at the top. It can be cut on the band saw with the sides held on edge in a fixture attached to the miter gage. All material is 5/16 in. solid stock.

Fig. 16-57. Musical mantelpiece.

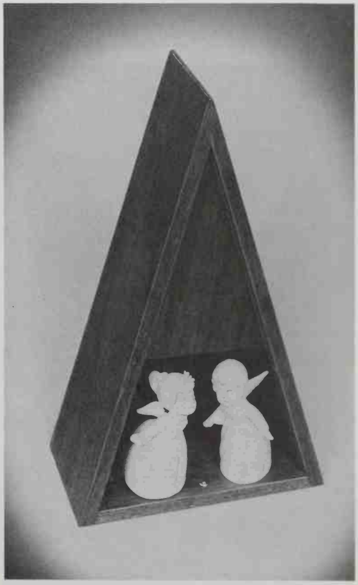


Fig. 16-58. Sconce.

SCONCE

Size: (main body) 4 x 5 3/4 x 9 1/2
(handle) 1 1/8 x 3 3/4, Fig. 16-58.

Design is based on an Early American scoop – an important utensil in pioneer homes. Base is 3/8 in. stock, while sides and back are 5/16 in. thick. Candle holder and handle are turned as separate pieces on the lathe, Fig. 13-12, page 75. Attach these pieces to the base with a single screw set in the bottom of the candle hole and extending through the base and into the handle below. Edge and butt joints are assembled with glue and brads.

CARVED FIGURE

Size: 15 in. high, Fig. 16-59.

Develop an attractive design and select a soft-textured wood with an interesting grain pattern. Cut out the blank on the jig saw and then use spokeshaves, chisels, files and sandpaper to complete the contours. Use metal pins made from nails to attach figure to base.

Fig. 16-59. Carved figure.

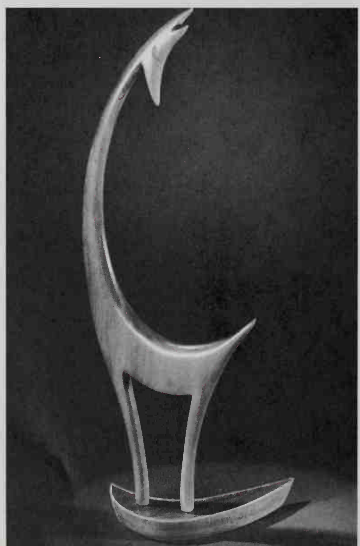


Fig. 16-60. Wall plaque.

WALL PLAQUE

Size: 3/4 x 7 x 12, Fig. 16-60.

Develop your design and then make a full sized pattern. Use solid stock that has an attractive grain pattern (walnut shown). You may need to glue up several pieces to secure the desired width. Spend lots of time smoothing the edges after you cut out the design. Use a leather thong for hanging.

SPOOL HOLDER

Size: (base) 7/16 x 4 in. diameter, Fig. 16-61.
(handle) 5/8 x 3 1/2 in. high
(feet) 3/4 in. diameter

Make the base from 7/16 in. stock. After smoothing both surfaces with a plane, lay out the diameter and the 6 peg positions. See page 27. The feet can be turned on the lathe as shown in Fig. 13-8, page 74. The stem or handle is turned between centers. See page 73.

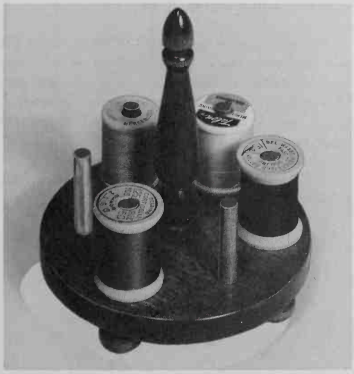


Fig. 16-61. Spool holder.

PULL TOY

Size: (body) 3/4 x 2 x 8, Fig. 16-62.
(wheels) 1/2 x 1 3/4

Basswood was used to make the project shown. Use a jig saw or coping saw to cut out the body. Smooth and round the edges with coarse abrasive

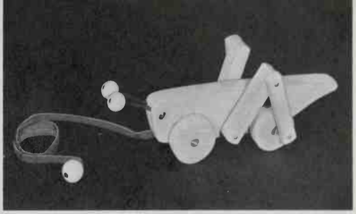


Fig. 16-62. Pull toy.

paper or a wood file. The wheels can be turned by mounting a round blank on a lathe faceplate. See Fig. 13-11, page 75. The moving legs are somewhat difficult to lay out and assemble. Making a full-sized drawing of these parts will prove helpful. A shoelace makes a good pulling cord.

TIC-TAC-TOE GAME

Size: 13/16 x 3 3/8 x 5 3/8, Fig. 16-63.

Use 7/16 in. stock for the base and 3/8 in. stock for the game board overlay. Use saw kerfs to separate the game area. You can turn the pegs from an assembly made of 1/4 and 5/8 in. dowels. See Fig. 13-8, page 74. Peg storage holes in the ends of the base should provide a snug fit. Game area holes need to be slightly oversize so the pegs can be easily inserted and removed.

Fig. 16-63. Tic-tac-toe game.

SPINNING TOP

Size: (starting handle) 3/4 x 1 3/4 x 6 1/2
(top) 3 1/2 in. diameter, Fig. 16-64.

This top will spin for two minutes or more. When making the starting handle, bore the holes before

Fig. 16-64. Spinning top.

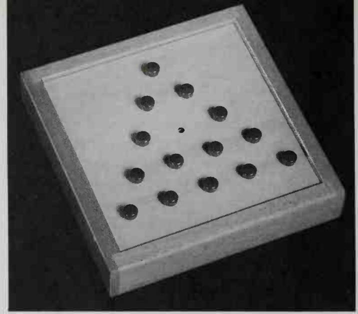


Fig. 16-65. Peg game.

cutting out the shape. The conical turning of the top can be eliminated and the 3/8 in. dowel extended down to form the spinning point. Make the starter cord from a shoe string and wooden bead. Wax the bearings for best performance.

PEG GAME

Size: 1 x 5 x 5, Fig. 16-65.

Base is formed by framing 1/2 or 3/4 in. particle board with 5/16 in. solid stock. Use rabbet or miter joints at the corners. Cover the top surface of the particle board with 1/32 in. plastic laminate. The plastic pegs shown were purchased at a school supply store.

SERVING TRAY

Size: 2 x 11 x 17, Fig. 16-66.

Use an attractive piece of 1/4 in. plywood and matching solid stock. Sides are 5/16 in. thick and ends are 1/2 in. thick. Cut grooves in sides and ends as shown in Fig. 12-15, page 69. Since it is easier to cut a groove all the way through, follow the suggestion shown in the drawing.

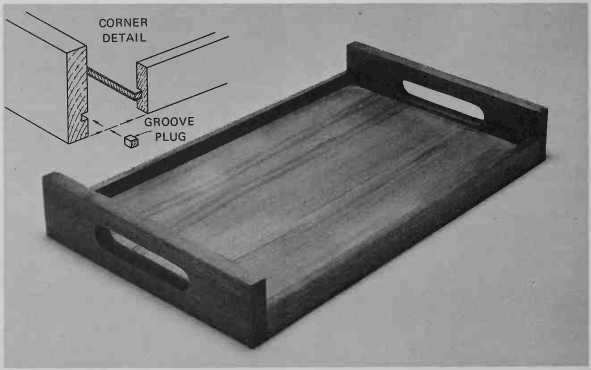


Fig. 16-66. Serving tray. Inset drawing shows construction detail.

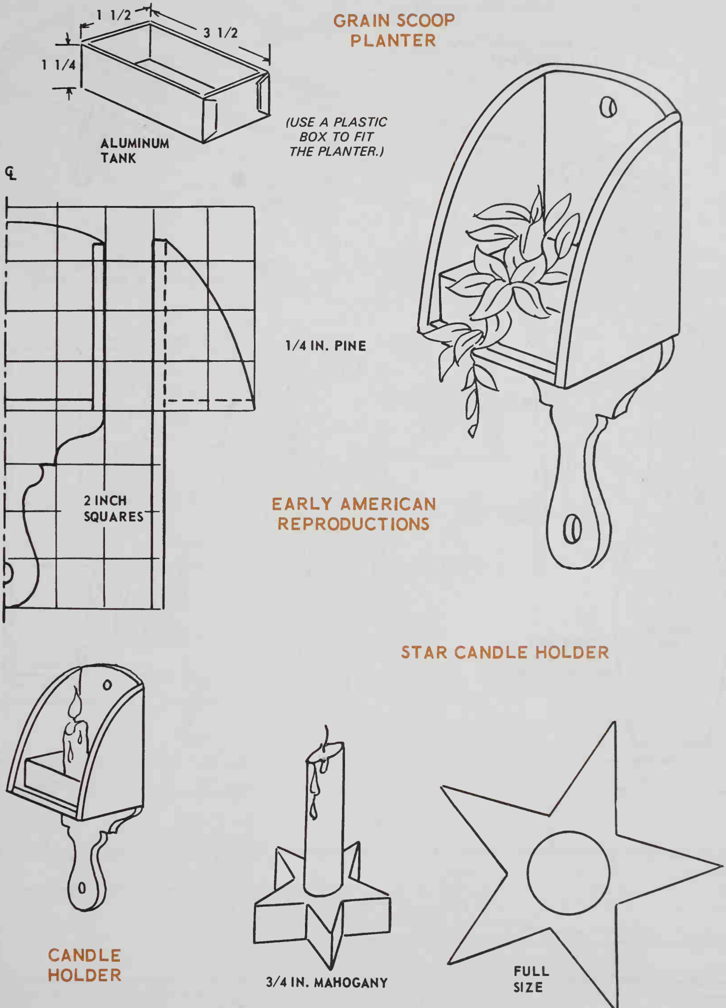


Fig. 16-67. Grain scoop planter and star candle holder.

EIGHT-FOOT BOWLING ALLEY

All 1/2 in. plywood, 3/4 in. pine legs.
Use 1 1/2 in. billiard balls.

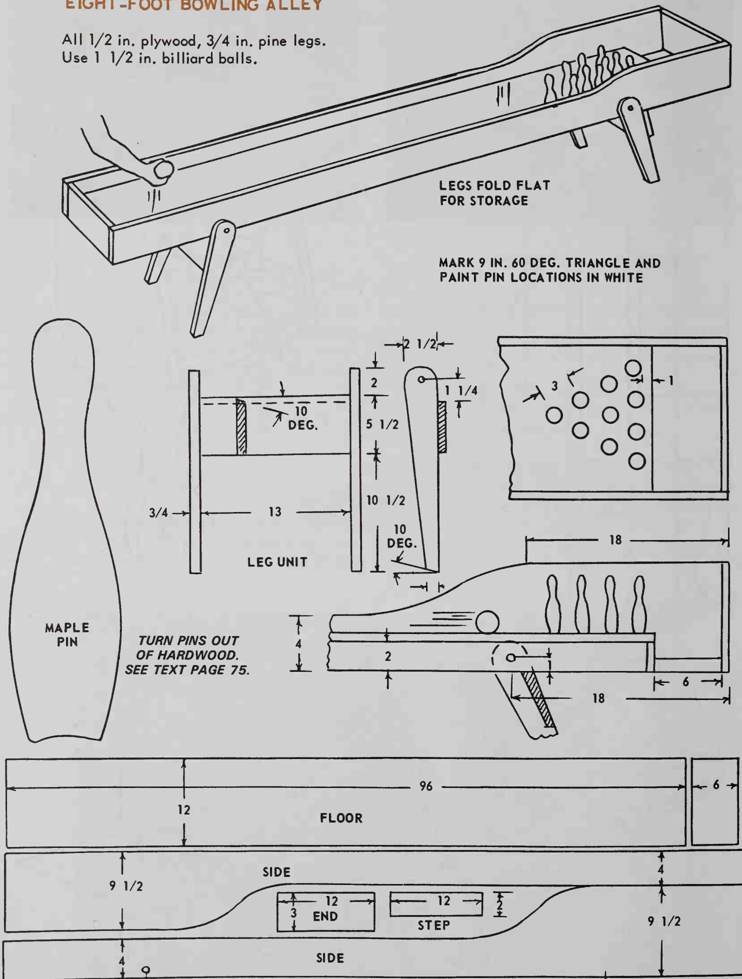
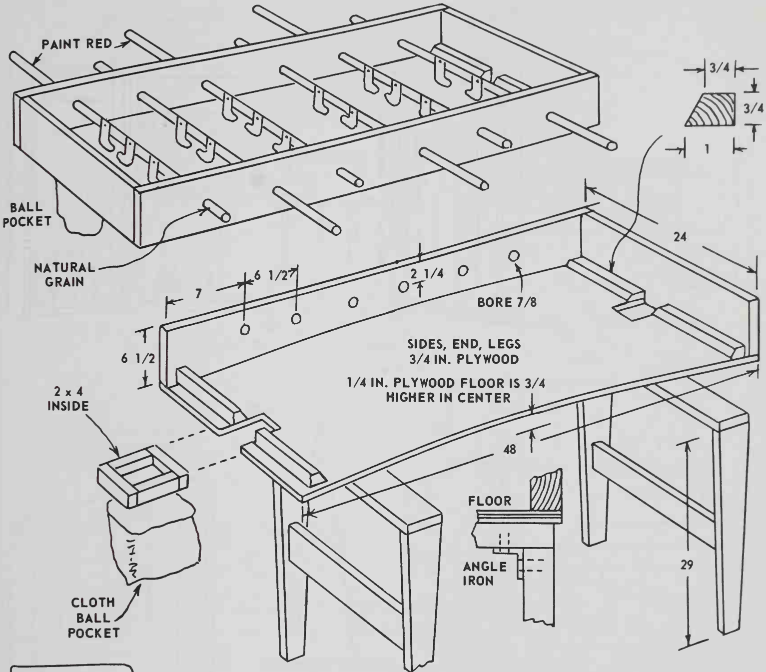
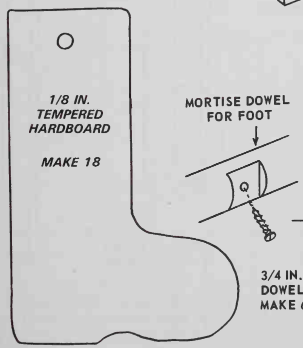


Fig. 16-68. Eight foot bowling alley.



SOCCER GAME

Ball (ping-pong or small rubber ball) is held above game at center and dropped. Players, one on each side, use rods projecting on side to sock ball toward goal, trying to get ball into pocket. Player getting most goals wins the game.



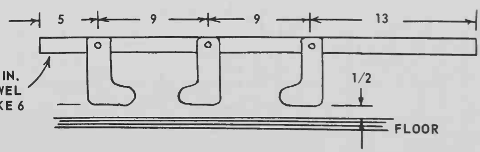
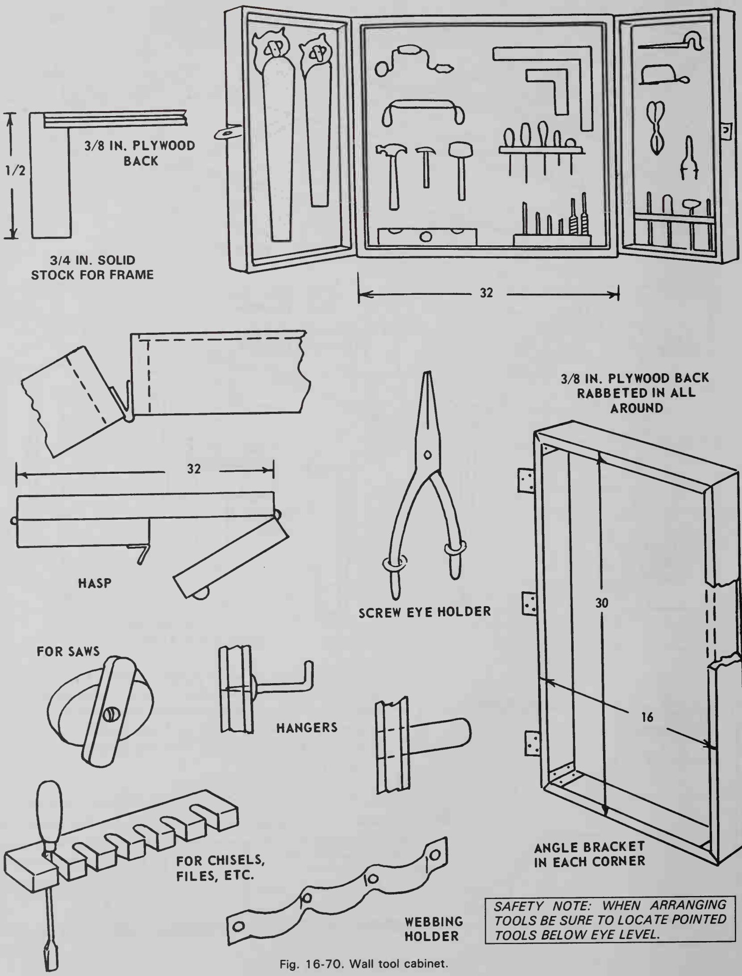


Fig. 16-69. Soccer game.

WALL TOOL CABINET



SAFETY NOTE: WHEN ARRANGING TOOLS BE SURE TO LOCATE POINTED TOOLS BELOW EYE LEVEL.

Fig. 16-70. Wall tool cabinet.

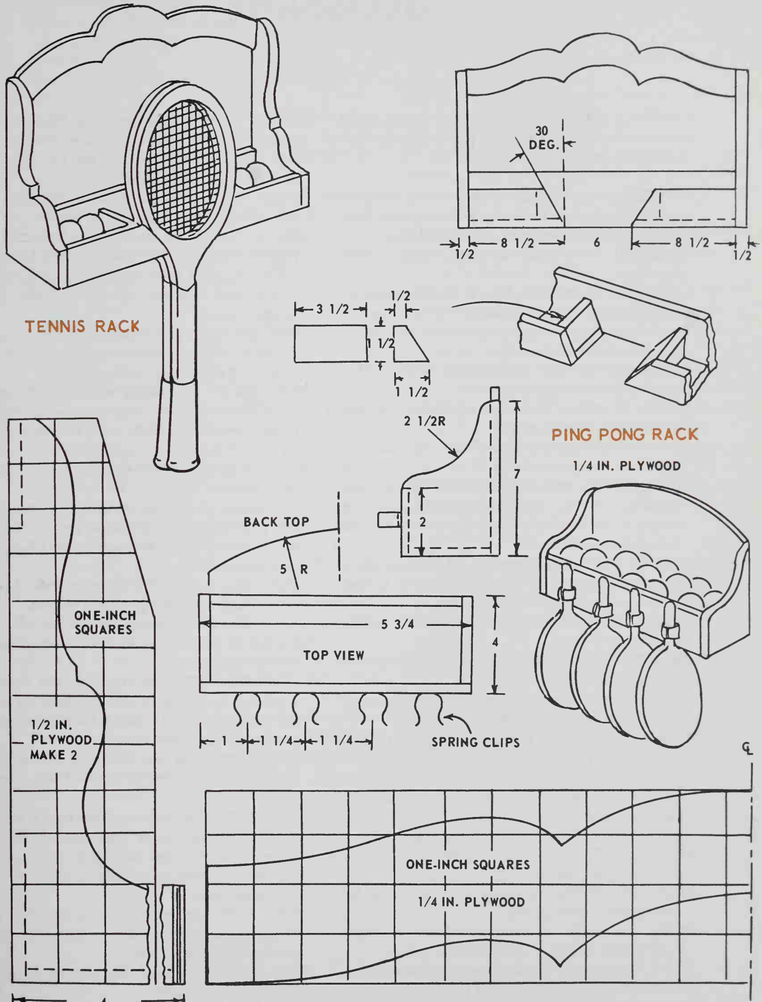


Fig. 16-71. Tennis rack and ping pong rack.

GLOSSARY

Here are some words that apply to woodworking and wood finishing, in addition to the ones used and defined in the instructional units.

ADHESIVE: A substance used to hold materials together by surface attachment. It is a general term that includes cements, glue, paste or mucilage.

ALIGN: To bring parts into proper position with each other.

ALUMINUM OXIDE: (Al_2O_3), an abrasive made by fusing Bauxite clay in an electric furnace. Used in the manufacture of grinding wheels, sharpening stones, and abrasive papers.

ARBOR: A short shaft or spindle on which another rotating part is mounted.

ARRIS: An outside corner or edge formed by the meeting of two surfaces.

BLEACHING: Lightening the color of wood by applying a chemical solution.

BLEEDING: The movement of stain or dye from the wood into surface coats. For example, a white enamel applied over a mahogany oil stain will bleed (develop pink spots).

BLUE STAIN: A stain caused by a fungus growth in unseasoned lumber. Often found in pine. It does not affect the strength of the wood.

BURL: A swirl or twist in the grain of the wood, usually near a knot.

CALIPER: A tool for measuring the diameter of circular work.

CHECKS: Small splits running parallel to the wood grain, usually caused by improper seasoning.

CHUCK: A broad term meaning a device for holding a rotating tool or work during an operation.

CLEAT: A strip of wood fastened to another piece, usually to provide a holding or bracing effect.

CLINCH: Nails made to hold more securely by bending down the ends of the protruding nails.

COUNTERBORING: To enlarge a hole through part of its length by boring.

COUNTERSINKING: To recess a hole conically for the head of a screw or bolt.

CORE: The center of a plywood panel. Plywood cores may be of either sawn lumber or veneer.

DADO: A groove cut across the grain of a board.

DUTCHMAN: A piece fitted into the work to cover a defect or error.

EARTH PIGMENTS: Pigments mined from the earth such as ochre, umber, sienna and vandyke brown.

FACE PLATE: A circular plate that can be attached to the headstock spindle of the lathe.

FENCE: An adjustable metal bar or strip mounted on the table of a machine or tool to guide the work.

FIGURE: The pattern produced in a wood surface by the annual growth rings, wood rays and knots.

FLOCK: Shredded cloth fibers. They are applied to a surface with a special adhesive to form a soft, felt-like finish.

GLUE BLOCKS: Small blocks of wood, usually triangular in shape, that are glued along the inside corner of a joint to add strength.

HARDBOARD: A material made by exploding (a steam process) wood chips into wood fibers and forming them into sheets, using heat and pressure.

HOLIDAYS: Areas of surface missed by a painter.

INLAY: A decoration where the design is set into the wood surface.

JIG: A device which holds the work and/or guides the tool while forming or assembling wood parts.

KERF: The slit or space made by the blade of any hand or power saw.

KNOT: Cross section of a branch or limb imbedded in the wood during the growth of the tree.

LAC: A natural resin secreted by insects that live on the sap of certain trees in oriental countries. The base for shellac.

LAMINATE: To build up wood in layers. Each layer is called a lamination or ply. The grain may run in the same direction in each lamination or may be turned at a right angle.

LINEAR: Pertaining to a line or consisting of lines. Linear measure refers to measurement along the length.

LINSEED OIL: A vegetable oil pressed from the seeds of the flax plant. Used extensively in the manufacture of oil base paints and finishes.

MANDREL: A shaft or spindle on which an object may be mounted for rotation.

MARQUETRY: An ornamental surface built up of various wood veneers to form a pattern or picture. Usually cut on the jig saw.

MESH: Openings formed by crossing or weaving threads, strings or wire.

MINERAL SPIRITS: A petroleum solvent used as a

substitute for turpentine.

MITER or MITRE: The joining of two pieces at an evenly divided angle. A cut made at an angle, usually 45 degrees.

OXIDIZE: To unite with oxygen — a chemical reaction.

PIGMENT: Finely ground powders that are insoluble and provide color and body to a finishing material.

PLAIN-SAWED: Lumber that is cut on a tangent to the annular growth rings.

QUARTER-SAWED: Lumber that is cut at approximately a 90 degree angle to the annular growth rings.

QUILL: The movable sleeve that carries the bearings and spindle of the drill press.

RABBET: A cut made in the edge of a board to form a joint with another piece.

RATCHET: A gear with triangular-shaped teeth that are engaged by a pawl, which imparts intermittent motion or locks it against backward movement.

RELATIVE HUMIDITY: The ratio of water vapor actually present in the air as related to the greatest amount of vapor the air can carry at a given temperature.

ROTARY CUT: A method of cutting veneer where the entire log is centered in a huge lathe and turned against a broad knife.

RPM: An abbreviation for revolutions per minute.

RUNS: Also called "sags" and "curtains." Irregularities in a surface finish usually caused by too heavy an application.

SABER SAWING: Cutting with a special blade mounted in only the lower chuck of the jig saw. Also applies to cutting with a portable saber saw.

SHAKE: A defect in wood running parallel to the grain caused by the separation of the spring and summer growth rings.

SILICON CARBIDE (Si C): Produced by fusing silica (sand) and coke at high temperatures. Used as an abrasive and sold under such trade names as Carborundum and Crystolon.

SLICED: A method of cutting veneer where a section of a log is thrust down along a knife edge that sheers off the veneer in sheets.

SPLAYED: Forming an oblique angle in the joining of two parts. Applies to the leg of a table or chair that make an angle in two directions with the top or seat.

SPLINE: A thin strip of wood inserted in matching grooves cut on the joining faces of a joint. Also, a flexible rod or rule used to draw curved lines.

STEAMED: This term, when applied to walnut lumber, refers to a process where the green lumber is steamed in vats for the purpose of darkening the sapwood.

STRAIGHTEDGE: A straight strip of wood or metal with opposite faces parallel. Used to lay out and check the accuracy of work.

TAPER: A gradual and uniform decrease in the size of a hole, cylinder, or rectangular part.

TEMPLATE: A pattern, guide or model that is used to lay out work or check its accuracy.

THINNERS: Volatile liquids that are used to regulate the consistency (thickness) of finishing materials.

TONGUE: A projecting bead cut on the edge of a board that fits into a groove on another piece.

TRACKING: Refers to the alignment of a blade as it runs on the band saw wheel.

TURPENTINE: A volatile solvent used in wood finishes, which is made by distilling the gum obtained from the pine tree.

VEHICLE: The liquid part of a paint.

VENEER: A thin sheet of wood, either sliced, cut or sawn. Veneer may be referred to as a ply when assembled in a panel.

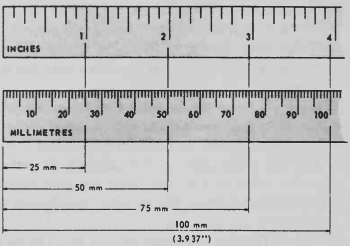
VOLATILE: A liquid that dries rapidly by evaporation.

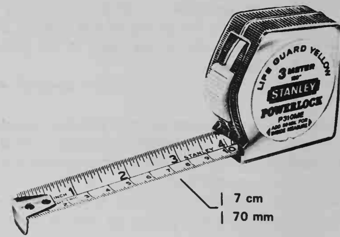
WANE: The presence of bark, or the lack of wood from any cause on the edge or corner of a piece of lumber.

WARP: Any variation from a true or plane surface. It may include bow, cup, crook or wind (twist).

WATER STAIN: Colored dyes that are soluble in water.

WATER WHITE: Transparent like water. Used to describe a very clear lacquer or varnish.





Typical dual dimensioned rule. Numbers on the metric side read in centimetres (cm). Multiply these numbers by 10 (add 0) to convert them to millimetres (mm).

INCH TO MILLIMETRES CONVERSIONS

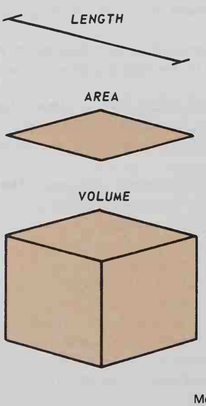
EXACT		ROUND OUT 0.5 mm	ROUND OUT 1 mm
1/32 IN.	0.794	1 mm	1 mm
1/16 IN.	1.588	1.5 mm	2 mm
1/8 IN.	3.175	3 mm	3 mm
1/4 IN.	6.350	6.5 mm	6 mm
3/8 IN.	9.525	9.5 mm	10 mm
1/2 IN.	12.700	12.5 mm	13 mm
5/8 IN.	15.875	16 mm	16 mm
3/4 IN.	19.050	19 mm	19 mm
7/8 IN.	22.225	22 mm	22 mm
1 IN.	25.400	25.5 mm	25 mm

CONVERSION ACCURACY

1/32 IN. 1/25 IN. 1/16 IN.

The size of a millimetre (1/25 in.) is about half way between 1/32 in. and 1/16 in. as shown above. For general woodworking, rounding a converted figure to the nearest millimetre is acceptable practice. When greater accuracy is required, round to the nearest 1/2 millimetre. See table at left. For sizes not listed, add combinations of figures (exact) and then round to accuracy desired.

METRIC CONVERSIONS FOR LENGTH, AREA, AND VOLUME



1 METRE (m) = 1 000 MILLIMETRES (mm) = 100 CENTIMETRES (cm)

1 m = 3.28 FT.	1 FT. = .305 m
1 cm = 0.39 IN.	1 IN. = 2.54 cm
1 mm = 0.0394 IN.	1 IN. = 25.4 mm

1 SQUARE METRE (m^2) = 10 000 SQUARE CENTIMETRES (cm^2)

1 m^2 = 1.2 $YD.^2$	1 $YD.^2$ = .836 m^2
1 m^2 = 10.8 $FT.^2$	1 $FT.^2$ = .093 m^2
1 cm^2 = .155 $IN.^2$	1 $IN.^2$ = 6.45 cm^2

1 CUBIC METRE (m^3) = 1 000 CUBIC DECIMETRES (dm^3)

1 dm^3 = 1 LITRE

1 m^3 = 1.31 $YD.^3$	1 $YD.^3$ = 0.765 m^3
1 m^3 = 35.3 $FT.^3$	1 $FT.^3$ = 0.028 m^3
1 cm^3 = .061 $IN.^3$	1 $IN.^3$ = 16.39 cm^3

Metric conversions for length, area, and volume.

CONVERSION TABLE
METRIC TO ENGLISH

WHEN YOU KNOW	MULTIPLY BY: * = Exact		TO FIND
	VERY ACCURATE	APPROXIMATE	
LENGTH			
millimetres	0.0393701	0.04	inches
centimetres	0.3937008	0.4	inches
metres	3.280840	3.3	feet
metres	1.093613	1.1	yards
kilometres	0.621371	0.6	miles
WEIGHT			
grains	0.00228571	0.0023	ounces
grams	0.03527396	0.035	ounces
kilograms	2.204623	2.2	pounds
tonnes	1.1023113	1.1	short tons
VOLUME			
millilitres		0.2	teaspoons
millilitres	0.06667	0.067	tablespoons
millilitres	0.03381402	0.03	fluid ounces
litres	61.02374	61.024	cubic inches
litres	2.113376	2.1	pints
litres	1.056688	1.06	quarts
litres	0.26417205	0.26	gallons
litres	0.03531467	0.035	cubic feet
cubic metres	61023.74	61023.7	cubic inches
cubic metres	35.31467	35.0	cubic feet
cubic metres	1.3079506	1.3	cubic yards
cubic metres	264.17205	264.0	gallons
AREA			
square centimetres	0.1550003	0.16	square inches
square centimetres	0.00107639	0.001	square feet
square metres	10.76391	10.8	square feet
square metres	1.195990	1.2	square yards
square kilometres		0.4	square miles
hectares	2.471054	2.5	acres
TEMPERATURE			
Celsius	*9/5 (then add 32)		Fahrenheit

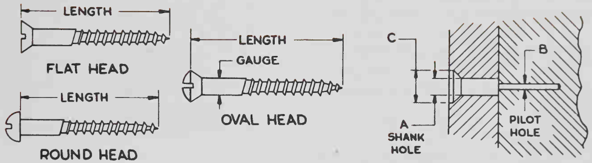
CONVERSION TABLE ENGLISH TO METRIC

WHEN YOU KNOW	MULTIPLY BY: * = Exact — VERY ACCURATE	MULTIPLY BY: * = Exact — APPROXIMATE	TO FIND
	LENGTH		
inches	* 25.4		millimetres
inches	* 2.54		centimetres
feet	* 0.3048		metres
feet	* 30.48		centimetres
yards	* 0.9144	0.9	metres
miles	* 1.609344	1.6	kilometres
	WEIGHT		
grains	15.43236	15.4	grams
ounces	* 28.349523125	28.0	grams
ounces	* 0.028349523125	.028	kilograms
pounds	* 0.45359237	0.45	kilograms
short ton	* 0.90718474	0.9	tonnes
	VOLUME		
teaspoons		5.0	millilitres
tablespoons		15.0	millilitres
fluid ounces	29.57353	30.0	millilitres
cups		0.24	litres
pints	* 0.473176473	0.47	litres
quarts	* 0.946352946	0.95	litres
gallons	* 3.785411784	3.8	litres
cubic inches	* 0.016387064	0.02	litres
cubic feet	* 0.028316846592	0.03	cubic metres
cubic yards	* 0.764554857984	0.76	cubic metres
	AREA		
square inches	* 6.4516	6.5	square centimetres
square feet	* 0.09290304	0.09	square metres
square yards	* 0.83612736	0.8	square metres
square miles		2.6	square kilometres
acres	* 0.40468564224	0.4	hectares
	TEMPERATURE		
Fahrenheit	* 5/9 (after subtracting 32)		Celsius

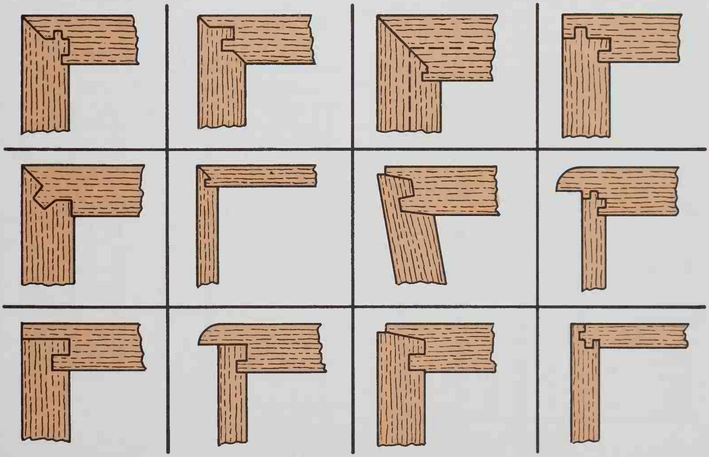
USEFUL TABLES

WOOD SCREW TABLE

LENGTH	GAUGE STEEL SCREW	GAUGE BRASS SCREW	GAUGE NO.	DECIMAL	APPROX. FRACTION	APPROX. METRIC DRILL EQUIV. (mm)	DRILL SIZE A	DRILL SIZE B	DRILL SIZE C
1/4	0 to 4	0 to 4	0	.060	1/16	1.5	1/16		
3/8	0 to 8	0 to 6	1	.073	5/64	2.5	3/32		
1/2	1 to 10	1 to 8	2	.086	5/64	2.5	3/32	1/16	3/16
5/8	2 to 12	2 to 10	3	.099	3/32	3.5	1/8	1/16	1/4
3/4	2 to 14	2 to 12	4	.112	7/64	3.5	1/8	1/16	1/4
7/8	3 to 14	4 to 12	5	.125	1/8	3.5	1/8	3/32	1/4
1	3 to 16	4 to 14	6	.138	9/64	4.0	5/32	3/32	5/16
1 1/4	4 to 18	6 to 14	7	.151	5/32	4.0	5/32	1/8	5/16
1 1/2	4 to 20	6 to 14	8	.164	5/32	5.0	3/16	1/8	3/8
1 3/4	6 to 20	8 to 14	9	.177	11/64	5.0	3/16	1/8	3/8
2	6 to 20	8 to 18	10	.190	3/16	5.0	3/16	1/8	3/8
2 1/4	6 to 20	10 to 18	11	.203	13/64	5.5	7/32	5/32	7/16
2 1/2	8 to 20	10 to 18	12	.216	7/32	5.5	7/32	5/32	7/16
2 3/4	8 to 20	8 to 20	14	.242	15/64	6.5	1/4	3/16	1/2
3	8 to 24	12 to 18	16	.268	17/64		9/32	7/32	9/16
3 1/2	10 to 24	12 to 18	18	.294	19/64		5/16	1/4	5/8
4	12 to 24	12 to 24	20	.320	21/64		11/32	9/32	11/16
4 1/2	14 to 24	14 to 24	24	.372	3/8	9.5	3/8	5/16	3/4
5	14 to 24	14 to 24							



MITER AND LOCK JOINTS

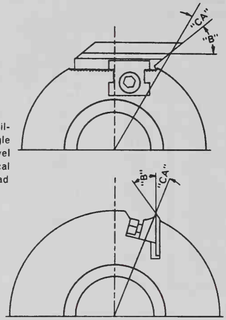


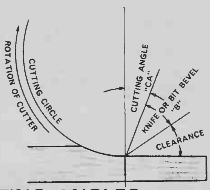
Typical miter and lock joint patterns used in the woodworking industry. Special cutterheads are used. (Wisconsin Knife Works)

Cutting Angles and Rates of Feed

CUTTING ANGLES

These sketches illustrate the cutting angle and knife and bit bevel relation on a typical milled-to-pattern head and a round head.





FINISH AND RATES OF FEED

Knife Finish Ranges Generally Recommended according to wood species:

Kind of Wood	Knife Marks per Inch
Ash	11 to 14
Basswood	8 to 12
Beech	12 to 14
Birch (plain)	12 to 14
Birch (curly)	13 to 16
Cedar	8 to 12
Cherry	12 to 14
Cottonwood	8 to 12
Cypress	8 to 12
Elm (hard)	10 to 13
Elm (soft)	8 to 12
Fir	8 to 12
Gum	9 to 13
Hemlock	8 to 12
Hickory	12 to 15
Mahogany (plain)	12 to 14
Mahogany (figured)	14 to 16
Maple	12 to 14
Oak	12 to 14
Pine (yellow)	9 to 13
Pine (white)	9 to 13
Poplar	9 to 13
Redwood	8 to 12
Spruce	8 to 12
Sycamore	11 to 14
Walnut	12 to 14

CUTTING ANGLES

	KILN DRIED 7% MOISTURE OR LESS		WET OR GREEN MORE THAN 7%	
	CA	B	CA	B
Ash	15°	35°	10°	35°
Basswood	10	30	20	30
Beech	10	35	15	35
Birch	10	35	15	35
Cedar	5	30	10	30
Cherry	10	35	15	35
Chestnut	5	35	10	35
Cottonwood	5	30	10	30
Cypress	5	30	10	30
Elm, Hard	0	40	5	40
Fir	10	35	15	35
Gum	20	35	25	35
Hemlock	15	35	20	35
Hickory	5	40	10	40
Mahogany	10	35	15	35
Maple	5	40	10	40
Oak	10	40	15	40
Oak Qtd.	10	40	15	40
Pine, Yellow	20	35	25	35
Pine, White	25	30	30	30
Pine, Ponderosa	25	30	30	30
Poplar	30	30	35	30
Redwood	5	30	15	30
Spruce	20	35	25	35
Sycamore	5	35	10	35
Walnut	5	35	10	35
Elm, Soft	5	40	10	40

RATES OF FEED

$$\frac{\text{R.P.M.} \times \text{No. KNIVES}}{\text{FT. PER MIN.} \times 12} = \text{KNIFE MARKS PER INCH}$$

R.P.M.	Knife Marks Per Inch	NUMBER OF KNIVES CUTTING				
		1	2	4	6	8
3600	10	30 Ft.	60 Ft.	120 Ft.	180 Ft.	240 Ft.
	12	25	50	100	150	200
	14	21	43	82	123	164
	16	18	37	73	112	146
	18	16.5	33.5	66.5	100	133.3
	20	15	30	60	90	120
4800	10	40	80	160	240	320
	12	33	66	133	200	266
	14	28	57	112	171	224
	16	25	50	100	150	200
	18	22.2	44	88	133	176
	20	20	40	80	120	160
6000	10	50	100	200	300	400
	12	41	83	166	250	332
	14	35	71	143	213	286
	16	31	62	125	185	250
	18	27	55	111	160	222
	20	25	50	100	150	200
7200	10	60	120	240	360	480
	12	50	100	200	300	400
	14	42	86	164	246	328
	16	36	74	146	224	292
	18	33	67	134	200	268
	20	30	60	120	180	240

(Wisconsin Knife Works Inc.)

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Western Wood Products Assoc., Portland, OR
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FOR YOUR FURTHER STUDY

Dunmire, Reba Ann, TOYS OF EARLY AMERICA, The Goodheart-Willcox Co., South Holland, Illinois.
Morris, Floyd, 192 EASY WOOD PROJECTS, The Goodheart-Willcox Co., South Holland, Illinois.
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INDEX

Goodheart Willcox's BUILD-A-COURSE® Series

metalworking

by

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INTRODUCTION

This book is one of a series planned specifically to provide general exploratory experiences in Technology Education and Industrial Arts. It is designed to provide a broad experience in METALWORKING through the use of tools, machines, and materials that are basic to this important area.

The book includes informational topics, general careers information, planning and designing, safety, bench metal, sheet metal, forging, welding, founding, heat treating, machine shop, and Computer Aided Manufacturing. Although some shops may not be equipped to teach all the areas presented, students will have an opportunity to read about the several areas of metalwork.

Hand tool operations are stressed since this course is designed for students who are beginning the study of metalwork, or have had very little experience in this area. Each unit progresses from the use of simple hand tools to some of the more basic machine operations, so students can gain the necessary background of information and skill needed as they progress to more advanced metalworking.

A number of shop-tested projects are presented which will help stimulate interest and provide a challenge. The projects range from simple construction jobs to some which are more complex.

The author hopes that this book will contribute to students' knowledge and skills needed for everyday living, as well as their pursuit of career and avocational interests.

T. Gardner Boyd

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CONTENTS

Unit 1
METAL IN OUR EVERYDAY LIVES

After studying this unit, you will know:
1. **Why you should study metalwork.**
2. **What the future holds for metalworking industries and employment.**
3. **What career opportunities are available in the areas of metalwork and related fields.**

A CHAT WITH YOUR TEACHER

The metalworking industries and their products play an important part in the lives of all of us. Through metal products our homes have been made more comfortable, sanitary, and convenient places to live. Our modes of transportation have become more luxurious and convenient with automobiles, streamlined trains, and jet airplanes.

Metals and metal alloys have played a very important part in the development of rockets and satellites. Metal undoubtedly will play an ever increasing roll as space ships and other items are developed for our adventures to other planets.

We are all consumers of metal products. Our homes are filled with items made of metal such as washing machines, refrigerators, metal furniture, automobiles, bicycles, and many other products which we use every day. To be an intelligent user of these articles you should be able to recognize good design and quality. The skills you learn in metalwork will help you as a consumer and will also enable you to repair and maintain many of these metal products. You may also develop a fascinating hobby making useful articles of metal.

METALS IN THE FUTURE

As we look into the future it is possible to visualize still further progress in the utilization of metal, especially when we consider our vast mining resource, huge steel mills, refining plants, and the progress our scientists are making in the development of new metal alloys. America's entry into the space age will create thousands of new and interesting jobs. In order to keep pace with the new developments in the aircraft, missile, and spacecraft field as well as our everyday needs, increasing numbers of engineers, scientists, technicians, and skilled craftworkers will be needed.

A recent census report reveals that more than 10 percent of the people in our country are directly or indirectly engaged in some phase of the metalworking field. There are many different career and job offerings in each area of metalwork. Industry needs engineers and skilled technicians to plan and supervise the work. Skilled craftworkers are needed to perform the more difficult machining and fabricating operations. Semi-skilled people are needed to operate production machines, and to do the many routine jobs.

CAREER OPPORTUNITIES

As you study the various areas of metalworking included in this book you will want to explore and become aware of the many exciting career opportunities that are available in this interesting field of work. While studying the metalworking careers you should find the answers to these questions:

1. What are the working conditions?
2. Is this the kind of work I will enjoy doing?
3. What kind of training or educational qualifications will be required?
4. Do I have the mental ability to complete the training successfully?
5. Can I meet the physical requirements?
6. What are the employment trends in this field of work?
7. What are the economic returns, including salary range, possibilities for promotion, vacations, sick leave, and retirement?

Metalworking — CAREER OPPORTUNITIES

	Careers
Bench Metal	Basic To All Metalwork
	Bench Repair Worker
	Ornamental Iron Worker
	Iron Worker, Shop Riveter
Forging	Tool Dresser
	Hammersmith
	Blacksmith
	Spring Maker
	Hand Drop Hammer Operator
	Forging Press Operator
	Angle Press Operator
	Bolt Machine Operator
Foundry	Bench Molder
	Finish Molder
	Machine Molder
	Chief Inspector
	Die Casting Machine Operator
	Coremaker
	Blast Furnace Keeper
	Electric Arc Furnace Operator
	Sand Control Worker
	Ladle Worker

	Careers
Heating Treating	Heat Treater
	Casehardener
	Tool Hardener
	Checker
	Material Tester
	Furnace Worker
	Temperer
Machine Shop	Machinist
	Machine Shop Supervisor
	Tool Supervisor
	Machinist, Bench
	Instrument Maker
	Tool and Die Maker
	Tool Maker
	Engine Lathe Operator
	Milling Machine Operator
Sheet Metal	Sheet Metal Worker
	Sheet Metal Layout Worker
	Furnace Sheet Metal Worker
	Construction Sheet Metal Worker
	Sheet Metal Supervisor
	Template Layout Worker

Fig. 1-1. Career opportunities in the fields of metalwork.

CAREER INFORMATION SOURCES

Each unit of study in METALWORKING has an overview of career opportunities pertaining to the area. However, you may want to do additional research and study about some of the metalworking industries in which you are interested. Your school counselor can provide information about educational and personal requirements. Additional information can be obtained from the following sources:

American Iron and Steel Institute, 150 East 42nd Street, New York, New York 10017.

American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, New York 10017.

American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

American Welding Society, 345 East 47th Street, New York, New York 10017.

Forging Industry Association, 55 Public Square, Cleveland, Ohio 44113

International Association of Machinists, 1300 Connecticut Avenue, N.W., Washington, D.C. 20036.

National Tool, Die and Precision Machinery Manufacturers Association, 907 Public Square Building, Cleveland, Ohio 44113.

Occupational Outlook Handbook, United States Government Printing Office, Washington, D.C. 20402.

Sheet Metal and Air Conditioning Contractors National Association, Inc., 107 Center Street, Elgin, Illinois 60120.

United Association of Journeymen, Apprentices, of Plumbing and Pipe Fitting Industries, 901 Massachusetts Avenue, N.W., Washington, D.C. 20001.

Fig. 1-1, lists areas of metalwork covered in this book, and a partial list of occupational classifications that offer excellent paying jobs.

It is impractical to offer, in the school shop, training in all of the specific careers listed in Fig. 1-1, so our course will be concerned with the basic skills involved in the various areas.

As you study this book and explore the various areas by constructing the projects you design, or those described in the Project Section, you will discover which areas you like best. If you enjoy metalwork and do well in your work, you should give serious thought to taking up some phase of metalwork as your vocation.

The aircraft industries provide many careers in the sheet metal trades and other skilled crafts. (Cessna Aircraft Co.)

Unit 2

DESIGNING METALWORKING PROJECTS

After studying this unit, you will know:
1. **The importance of good design.**
2. **Basic principles of good design.**
3. **Why it is necessary to know about materials used in metalwork when designing metal projects.**

GOOD DESIGN

Design is more important in our every day lives than we sometimes realize. Did you ever stop to think about the part it played in the development and construction of the home you live in, and the furniture you use? Cars, airplanes, and rockets have all been developed from drawings on paper. Many of these products are pleasing in looks; some are not. You will want to learn to sense and recognize the good qualities in design so you can be a good judge of consumer products.

Our great industrial development has been successful largely because new and better ideas for products, processes, and machines are constantly being developed. Probably one of the biggest reasons the United States has become the leading nation in the world, is because each of us want new, different, and better products. To keep ahead, our country needs people who can think seriously and creatively for themselves.

CAREER OPPORTUNITIES

There are many excellent careers in the design field. They range from jobs as design drafters to design engineers. Designers create or draw designs for the construction of articles. They may develop designs for machinery, apparatus or equipment. Designers will draw up construction details, determine production methods and standards of performance. Design engineers, for example, check designs to see if the items can be constructed with the manufacturing equipment available. If new equipment is needed, they check its availability and cost. Tool designers develop new tool designs, jigs and special fixtures for a specific function, and they frequently redesign tools to improve efficiency. Professional designers must have a background of knowledge in machine shop practice, drafting, shop mathematics, and characteristics of the materials to be used. As you pursue this metalworking course you will have an opportunity to perform some of the jobs of a designer.

DESIGNING YOUR PROJECT

You can learn to design as you develop the projects you build in metalwork. Designing begins with a problem. It may be to invent and create a new product or to improve one that is already in use. Typical questions you will want to answer regarding the designing of your project are:

1. What is it for? What is the purpose of the project and what must it do?
2. Are there any limitations involved? For example, if you are not allowed to use certain machines, can all parts be made without them? Other limitations might be the availability of materials or processes to be used.
3. Has the problem been solved by others, if so, how can it be improved? Can it be designed to meet your particular needs?

After you can answer these questions satisfactorily your next step is to:

1. Make several freehand sketches of your ideas so they can be studied by you and your teacher. While studying your sketches, consider several different designs of the project and the kind of material to be used for each part.
2. Make desirable changes. Then, make a working drawing which can be used to guide your construction of the project. Also make full-scale drawings of the parts which have irregular shapes.

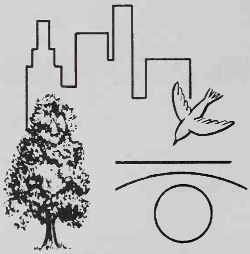


Fig. 2-1. Combinations of lines are used to form shapes.

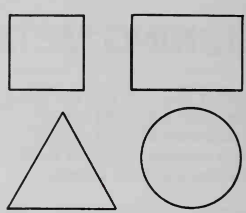


Fig. 2-2. Four basic shapes.

3. Decide what kinds of material you will use. Is one kind of metal to be used or a combination of metals? Will you use bars, sheet, pipe or cast metal?
4. Plan the procedure you will follow to construct your project.

As you design projects, you will need to consider certain basic elements and principles that make up the overall design of an article. Study the following basic elements and principles of design:

1. Line. All things we can see have line. Buildings, cars, trees, flowers and birds are all made up of lines, Fig. 2-1. There are three principal types of line – straight, curved and circular. These lines, when properly combined, give an article a pleasing shape.
2. Shape. There are four basic shapes – square, rectangular, triangular and round, Fig. 2-2. You see these shapes, or a combination of these shapes, when you look at natural or manufactured objects. Shape is influenced by function.
3. Mass or Solid. The solid shape or outline of an object has dimensions of thickness, width and height. When you look at an object, the mass may be square, round or some other geometric form, Fig. 2-3. You will use rods, bars, cubes and sheets of metal in developing your projects to make up a Mass or Solid shape.
4. Proportion. The relationship between dimensions is called "proportion." Proportion may be given as a ratio. The "golden rule" is a proportion of about 5 to 8. Odd ratios such as 3 to 5, 7 to 9, 9 to 11 are usually preferable. Rectangles, ovals

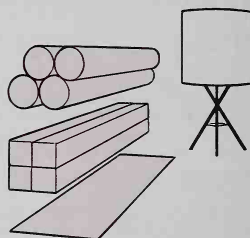


Fig. 2-3. Rods, bars and sheets of metal are used to make up a larger shape or mass.

and free forms are more pleasing as a rule than are squares and circles, Fig. 2-4.
5. Balance. An object has balance when its parts appear to be of equal weight – neither top heavy, nor bottom heavy, nor lopsided. There are two kinds of balance:
   Symmetrical Balance occurs when the parts on each side of the center are alike in shape and size. See Fig. 2-5 (A).
   Informal Balance occurs when the design is such that the balance cannot be measured or laid out with a ruler, and yet you get the feeling that it is balanced. See Fig. 2-5 (B). A design with informal balance usually is more interesting than one with symmetrical balance.
6. Unity. A design that has unity seems to bring the various parts together as a whole. Each part of the object seems to have a relationship and your

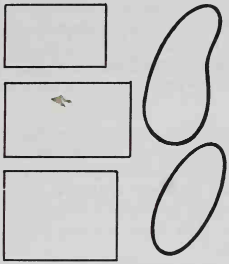


Fig. 2-4. Rectangles and free forms.

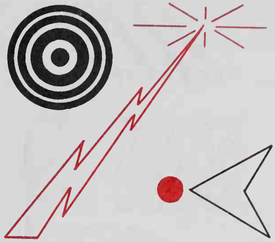


Fig. 2-6. Emphasis is brought out through shape, color, or decorations.

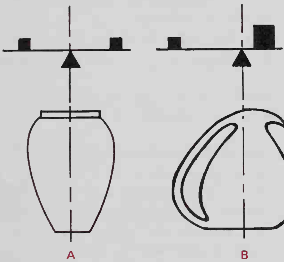


Fig. 2-5 (A) Symmetrical balance. (B) Informal balance.

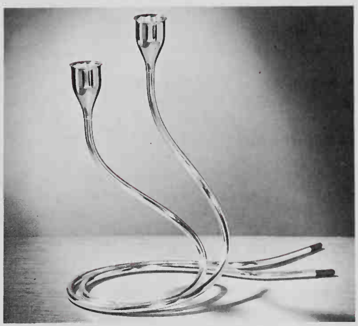


Fig. 2-7. In these candlesticks lines and curves are repeated to create rhythm.

Fig. 2-8. In this design, harmony is obtained by using parts that fit and look well together.

eyes follow through and among the various parts with ease.

7. Emphasis. The design is given a point of interest. A certain part of the object may stand out through the use of color, its shape or the way it is decorated, Fig. 2-6.
8. Rhythm. Rhythm is achieved by repeating lines, curves, forms, colors, and the textures within the design. It gives an object a feeling of movement and a pleasing appearance, Fig. 2-7.
9. Harmony. Harmony results when the different parts of a design fit and look well together, Fig. 2-8. Too much harmony can make a design monotonous and uninteresting. Variety is then needed to make it more pleasing.
10. Texture. Texture is the condition of the surface of a material. Many metals have texture ranging

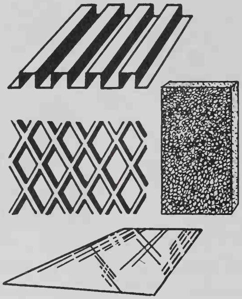


Fig. 2-9. Texture can be added by hammering, perforating, cutting, or forming the metal.

from a smooth to a very coarse surface. Texture can be added by perforating, cutting, pressing, rolling, or expanding, Fig. 2-9. When applying texture to your design be sure it is appropriate to the article, and to its function.

11. Color. All metals have a color of their own. For example, aluminum is silvery, while copper is a rich reddish brown. Colors may also be added by using lacquer, paint, chemicals, or other finishing materials. The selection of color is important in any design. Colors must be chosen carefully, or they may ruin a perfectly good project. Ordinarily, one color should be dominant in the design. The main color should be appropriate for the project. The qualities of colors should be considered. Some colors, such as red, orange, and yellow have warmth while other colors, such as blue, purple, and green are cool.

SELECTION OF MATERIALS

In order to design and construct quality projects in metal work, you will need to become familiar with some of the more common materials used. It will be necessary for you to know something about the various properties of metal and the shapes and sizes available.

Metal is one of the most common elements found on earth. Some of the metals mined are: aluminum, copper, gold, silver, and iron. You have probably heard someone speak of an alloy. An alloy is a combination of two or more metals melted and mixed together in certain proportions. For example, brass is a metal alloy which is produced by mixing copper and zinc. The properties of base metals and metal alloys vary widely. Among these properties are:

1. Hardness, the resistance to surface abrasion or penetration. Metal becomes harder as it is worked (by hammering on it) and by heat treating (explained in Unit 8). The harder the metal, the less likely it is to bend or change shape. Hard metals are more brittle than soft metals.
2. Malleability, the ability to be shaped by rolling out or hammering when cold.
3. Ductility, the ability to undergo deformation (change of shape) without breaking.
4. Elasticity, the ability to return to the original shape after deformation.
5. Fatigue Resistance, the ability to resist repeated small stresses.

The metals you will use for projects will come under the following classifications:

1. Ferrous Metal (made from iron)
   a. Low-carbon steel which is often called mild steel, contains about 0.15 to 0.30 percent carbon. This is not enough carbon to harden the steel to any appreciable degree. This type of steel may be purchased in sheets, bars, and rods. It is easily formed, machined, and welded. You will use low-carbon steel for some of the projects you construct in bench metal work.
   b. Medium-carbon steel contains about 0.30 to 0.60 percent carbon. This type of steel works well for parts of projects which require machining.
   c. High-carbon steel contains from 0.60 to 1.00 percent carbon. It is sometimes referred to as tool steel. Most school shops use high-carbon steel that has about 0.90 percent carbon for chisels, punches, and similar projects, since this steel can be hardened and tempered.
2. Nonferrous Metal (made without iron)
   a. Aluminum is a bright, silver metal which is light in weight and strong. There are many alloys of aluminum but most school shops stock only the softer kind, such as 1100-0 and 3003-0 in sheets. Rods, bars, and angles

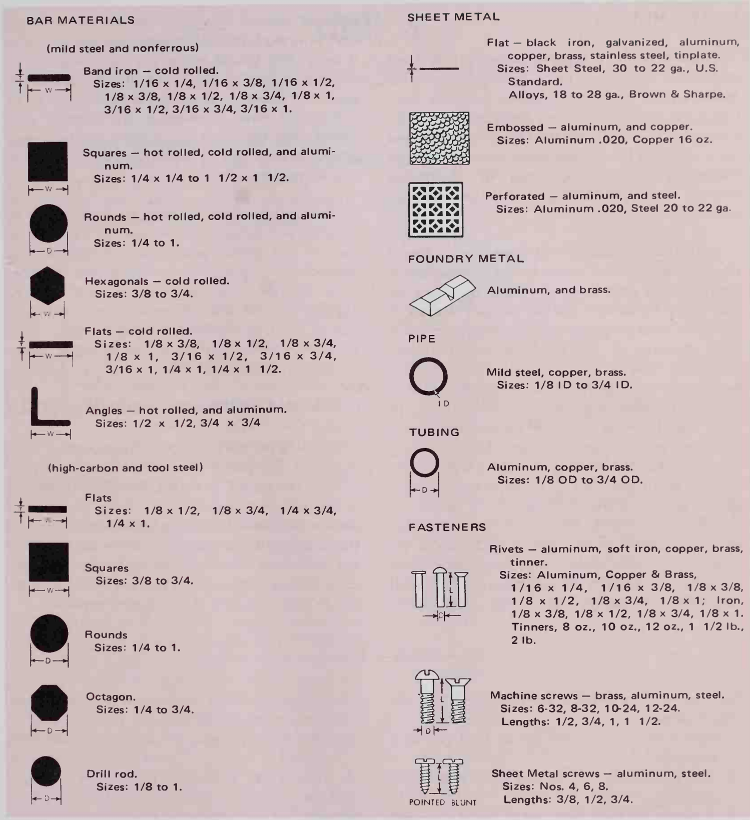


Fig. 2-10. Materials commonly used in metal work.

are used which have a harder temper. Aluminum alloys 43 and 108 are used for sand casting in the foundry. Aluminum is also used to construct bench metal, sheet metal, art metal, and machine shop projects.

b. Brass is an alloy of copper and zinc. It has a gold color. It is very ductile (may be hammered or drawn out thin) and easy to saw and file. Brass provides a very interesting color contrast when used with other metals.

c. Copper has a rich reddish brown color. It is easy to form and solder, but is hard to machine. Copper takes a beautiful polish. It is used for decorative articles such as bowls, trays, and lamps. It is also an excellent conductor of electricity.

EXOTIC METALS

You may want to do some research to find out more about some of the metals that are being used in atomic energy and space programs. Although scientists and engineers have known about these metals for some time, their use in the field of atomic energy and space programs has brought about more information concerning their characteristics of exceptional strength, rigidity, and the high temperatures they can withstand.

Beryllium, columbium, and titanium are a few of the more widely used metals in the construction of new space age craft being developed. Beryllium, for example, is lightweight and can be easily worked. It maintains good properties even at elevated temperatures. Because of the brittleness of this metal, technicians have encountered problems in forming beryllium. Although its principal use has been in alloys with copper, pure beryllium is proving to be quite useful in the field of atomic energy as a moderator and reflector in nuclear reactors. Columbium is a chemical element that has a high melting point of about 4380 deg. F. It retains good strength up to approximately 2000 deg. F. It resists the actions of most acids. Because of these characteristics, manufacturers are researching its use in the production of some space vehicle parts. Metallurgists are experimenting with the use of this metal for parts used in nuclear reactors, since it has a resistance to radiation damage. Titanium compares to low alloy steel in strength but weighs about one half as much. It can be heat treated and retains high strength up to approximately 1100 deg. F. With the development of supersonic aircraft, titanium has become important as a structural metal. Researchers are presently concerned with improving its qualities by developing protective coatings and discovering cheaper methods of processing this metal.

Many other metals are being researched, such as tantalum and tungsten, as we look for metals to be used in our atomic and space age technological developments. Tantalum is a white, ductile, malleable metal having a melting point of 5162 deg. F. Tungsten is silver white in color, ductile, and has a melting point of 6116 deg. F, which is higher than any other metal. The future use of these metals should be very exciting.

COMMON SHAPES AND SIZES OF METAL

Choosing the correct metal for your project is very important. The proper size must be selected so your finished project will be strong, durable, and meet all of the principles of good design. Study Fig. 2-10, to become familiar with the various shapes, sizes, and characteristics of the more common metals. Fig. 2-10, also shows the most common metal fasteners. Become familiar with them so you can decide the best way to fasten the parts of your project together.

QUIZ – Unit 2

Write answers on separate sheet of paper. Do not write in book.

1. How will the study of design help you as a consumer?
2. List three things to consider when designing a project _______, _______, and _______.
3. What do the basic elements of design, line and shape have in common?
4. The solid shape or outline of an object has dimensions of _______, _______, and _______.
5. The relationship between dimensions is called _______.
6. Rectangles, ovals, and free forms are more pleasing as a rule than, _______ and _______.
7. Explain the difference between symmetrical balance and informal balance.
8. What is the purpose of emphasis in designing a project?
9. Texture can be added to metal by _______, _______, _______, or _______.
10. List five properties of metals.
11. Ferrous metal is made from _______.
12. Nonferrous metal is made without _______.
13. High carbon steel contains from _______ to _______ percent carbon.
14. Medium carbon steel works well for parts of a project requiring machining. (True or False?)
15. Brass is an alloy of _______ and _______.

Unit 3
METAL SHOP SAFETY

After studying this unit, you will know:
1. The importance of a proper attitude toward safety.
2. Safety guides for dressing properly.
3. How to use metalworking tools safely.
4. Good housekeeping safety guides.

"Hi. I'm Chip. My ambition is to help you learn to work safely with tools, machines, and other equipment found in shops, and around the home so you won't get hurt. Injuries are painful and can be very serious. Many accidents occur because people are not informed. My job is to keep you informed and warn you when there is danger involved.

Study this lesson thoroughly and learn the safety guides listed. Watch for me as you study other lessons. I will be around to keep you informed and remind you about safety.

The proper safe attitude is very important in preventing accidents. This attitude is developed by accepting the guides and rules described in this book and demonstrated by your teacher. Safe practices and proper methods are for you, and not just the other fellow's. You are not a "sissy" if you wear goggles and use guards — you are smart. Just remember the right way is the safe way.

A football uniform is designed to overcome some of the hazards of the game. You know the dangers in playing the game without being properly dressed. The same holds true for the metalworker. While working in the metals area always dress properly for the job to be done and follow these guides:

1. Roll your sleeves above your elbows.
2. Remove your tie or tuck it in your shirt.
3. Remove wrist watch, rings and other pieces of jewelry which might get caught in moving machinery.
4. Keep your hair cut short or wear a shop cap to keep long hair from getting caught in machinery.
5. Wear a shop coat or apron to protect your clothing.
6. Wear special protective clothing when working in foundry, forging, and welding.
7. Wear safety goggles or a face shield when drilling, grinding, buffing or when there is danger of flying chips.
8. Wear special goggles or shield when welding.

It has been said that a good mechanic seldom gets hurt. A good mechanic takes proper care of the tools he uses. Records show that most minor accidents are caused by incorrect use of hand tools, or the tools have not been kept in good repair. When you are working with tools in the metals area always follow these guides:

1. Do not use a tool until you have had a demonstration.
2. Report any defective or broken tool you find to the teacher.
3. Dull tools are dangerous and will not work properly. Keep all cutting edges sharp.
4. Check hammer handles to be sure they are not cracked, and are fastened tightly.
5. Never use a file without a handle.

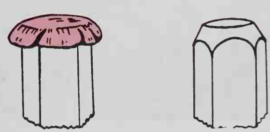


Fig. 3-1. The cold chisel at the left has a mushroom head. The one at the right is properly ground.

6. Always grind mushroom heads and burrs off chisels, punches, and other hand tools, Fig. 3-1.
7. Never carry sharp tools in your pocket.
8. Always carry tools and projects so their points or sharp edges are pointing down. If this is impractical, protect sharp edges and points with heavy paper, pieces of wood, or a metal sheath.
9. Be sure your hands are dry when using portable electric hand tools. Do not stand in a wet spot, touch plumbing, or other grounded objects while using electrically powered tools.
10. Always ground portable electric hand tools. Check the electrical cord, connections, plug, and switch to be sure they are in good condition before using.
11. Do not use electrical tools around inflammable gases or vapors. This could cause an explosion.

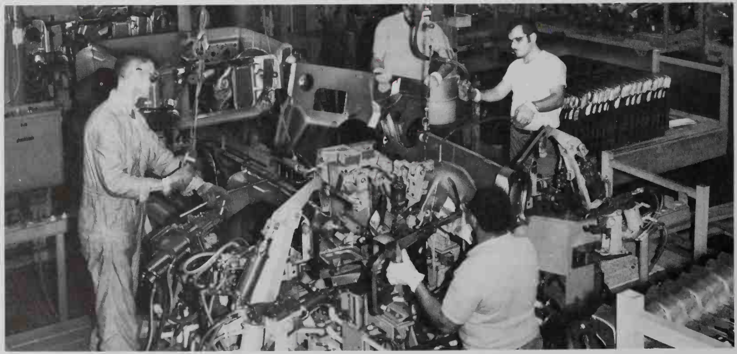
To complete your safety program you will want to establish some good housekeeping guides. A clean and orderly shop provides a safe place to work. You will want to do your part in keeping the shop clean and in order. Clean the bench or machine after you have finished your work. Clean and put away all tools and accessories when you have finished using them. Wipe up any oil or grease which might have dropped on the floor. As you work in the shop you will discover other things you can do to make it a safer place to work. Always be alert for any situation that might cause an accident.

Remember these basic guides of safety and practice them:

1. Dress properly for the job.
2. Protect your eyes at all times.
3. Know your job and do it correctly.
4. Be a good housekeeper.
5. When in doubt check with your teacher.

QUIZ — UNIT 3

1. Describe the proper way to dress in the shop.
2. How are the eyes protected when:
   a. grinding?
   b. drilling?
   c. welding?
3. Why is the proper attitude an important factor in shop safety?
4. Why is it necessary to remove jewelry when working with moving machinery?
5. What kind of hand tools are most dangerous?
6. How should sharp tools be carried?
7. Why is it advisable to grind mushroom heads off chisels and punches?
8. List three safety precautions to be observed when using a portable electric drill.
9. Why is it dangerous to use electrical tools around inflammable gases or vapors?
10. Why is good housekeeping an important part of a shop safety program?



The sheet metal trades offer a variety of careers which start with the operation of production machines to the highly skilled craftworker who performs the operations with hand tools and machines. (General Motors Corp.)

Unit 4
BENCH AND WROUGHT METAL

After studying this unit, you will know:
1. **How to use measuring and layout tools.**
2. **Cutting and drilling.**
3. **Bending and forming metal.**
4. **Cutting internal and external threads.**
5. **Fastening metals together.**
6. **Polishing and buffing metal.**

Bench metal is basic to all areas of metalwork. It deals with the use of common hand tools and information necessary for all workers in the metal trades. In this area of metalwork you will learn to use hand tools for laying out, cutting, shaping, forming, drilling, threading, assembling, and testing work at the bench. You will be working with mild steel, aluminum, copper, etc. The metal will be in the form of rods, squares, flat bars, and sheet stock of various sizes and thicknesses. The metal is worked cold with hand tools and a few machines such as the drill press, grinder, and buffer. It is very important that you learn to use the hand tools which will be introduced in this unit because you will use many of them in other units of metalwork.

CAREER OPPORTUNITIES

Using hand tools correctly is often more difficult than operating some machines. A metalworker must be able to use hand tools skillfully. Aviation mechanics, auto mechanics, machine repairers and assemblers, to mention a few, offer excellent job opportunities to people who can use bench metal tools correctly.

Skilled bench metal workers must know how to read blueprints, engineering specifications, and use a variety of tools including precision measuring instruments. Some of the new fields that have appeared in the last few years, such as missile subassembly, work on instrumentation, and electronics components, require a very high degree of skill.

Learning to use hand tools will be very valuable to you regardless of how you earn your living. You will be able to take care of maintenance jobs around your home. Many have found bench-metal work to be a very interesting and satisfying hobby. It does not cost as much to equip a home work shop for bench-metal work as some other hobbies. You can make many useful items for your home and gifts for friends.

MEASURING AND LAYING OUT STOCK

The first steps in constructing a project are to measure your stock and mark it to the correct size, then transfer your patterns to the material being used. Making accurate measurements is very important in the production of high-grade work. To do this you will want to learn to use the following measuring and layout tools correctly.

RULES

The most widely used tool for taking and laying out measurements is the steel rule. Rules vary in lengths, widths, and thicknesses. The most common

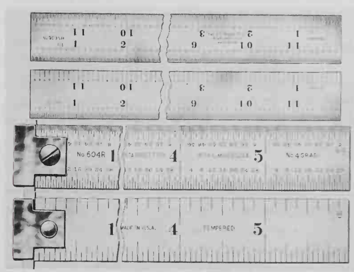


Fig. 4-1. Above. Two sides of a spring-tempered steel rule. Below. Two sides of an adjustable hook rule. (L. S. Starrett Co.)

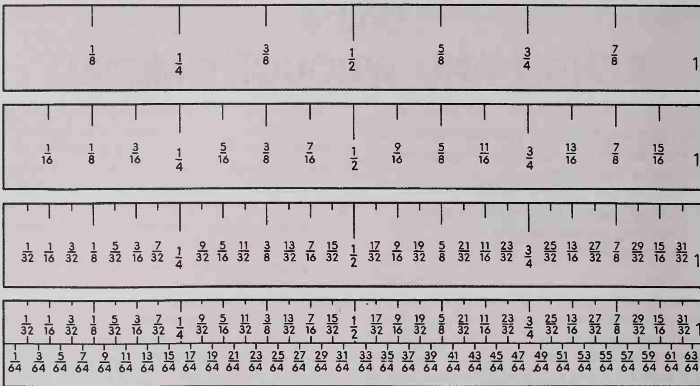


Fig. 4-2. Chart showing a comparison of the divisions on a rule.

being 6, 12, and 24 inches in length. Along each edge of the rule and on both sides, the inch marks are divided into various subdivisions. The first edge is divided into sixty-fourths of an inch. The second edge is divided into thirty-seconds of an inch and the third edge into sixteenths of an inch. The fourth edge, and the one you will use most is divided into eighths of an inch. Several types of steel rules with which you should become familiar are shown in Fig. 4-1.

Incorrect measurements in layout cause serious trouble in metalworking. Be sure you can read a rule. Study the chart shown in Fig. 4-2.

SCRIBER

A scriber is a pointed steel instrument which is used to scribe or scratch lines on most metal surfaces, Fig. 4-3. It is held in the same manner as a lead pencil, Fig. 4-4. Keep the point true and sharp.

Fig. 4-3. A scriber. (L. S. Starrett Co.)

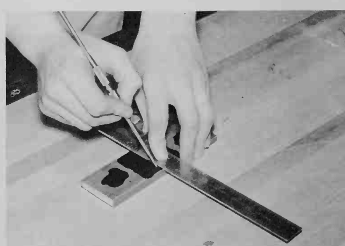


Fig. 4-4. Hold the scriber like a pencil.

SQUARES

The combination square set, with its four principal parts is a very useful measuring and layout tool, Fig. 4-5. The four parts are blade, combination square head, center head, and protractor head.

The blade which is available in lengths from 4 in. to 24 in. has graduations marked on all four edges. These graduations are usually 64ths, 32nds, 16ths, and 8ths. A groove runs along the center of the blade on one side and serves as a guide for clamping the heads. Each head can be slipped to any position along the length of the blade, and held in place with a knurled nut.

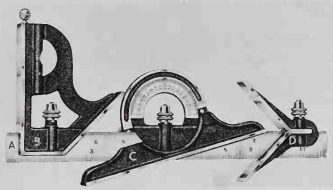


Fig. 4-5. Combination square set. A–Blade. B–45 and 90 deg. square head. C–Protractor head. D–Center head.

The combination square head has a straight edge which forms a 90 deg. angle with the blade on one side, and a 45 deg. angle on the opposite side. This head, Fig. 4-6, has many uses.

The center head has two projecting arms which form an inside angle of 90 deg. This head is used to locate centers of round stock. To use it for this purpose, place the center head against the stock with the blade on the top surface, Fig. 4-7, and scribe a line along the blade edge. Move the tool around the stock, and scribe two or more lines approximately the same distance apart. The exact center of the stock will be at the intersection of these lines.

The protractor head has a straight edge with a revolving turret in the center. The revolving turret is divided into 180 degrees. It is used to lay out or check any angle from 0 to 180 degrees. To draw

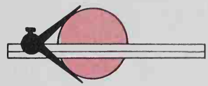


Fig. 4-7. Using the combination square center head.

angular lines, clamp blade to turret, set the blade at required degree, and lock in place with knurled nut. Then, place straight edge of head against edge of stock with blade across the surface, and scribe a line along the edge of the blade, Fig. 4-8.

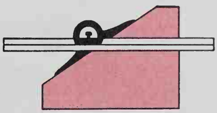


Fig. 4-8. Using the combination square protractor head.

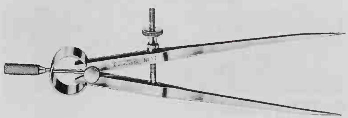


Fig. 4-9. Dividers. (L.S. Starrett Co.)

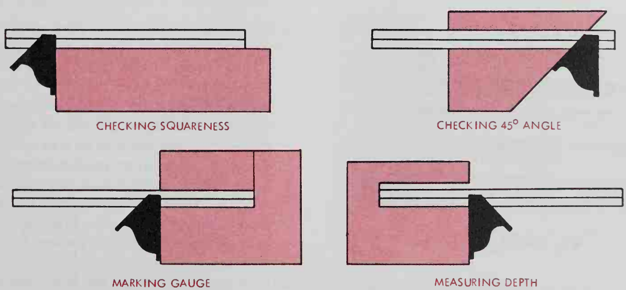


Fig. 4-6. Uses of the combination square head.

DIVIDERS

Dividers are used for measuring or setting off distances, and to lay out arcs and circles, Fig. 4-9. The procedure for using the dividers is the same as using a pencil compass in drawing.

PRICK PUNCH

The prick punch is a small center punch which is also known as a layout punch. Its point is ground at an angle of 30 degrees. It is used to accurately mark holes and other locations to be machined, Fig. 4-10. Keep the point true and sharp.

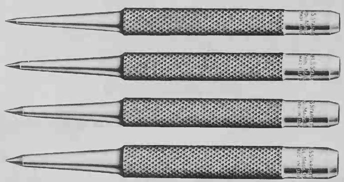


Fig. 4-10. A set of prick punches.

CENTER PUNCH

The center punch has one end ground to a 90 deg. conical point, Fig. 4-11. It is used to enlarge prick punch marks and make it easier for the drill to start correctly. Keep the point true and sharp.

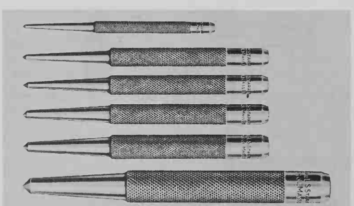


Fig. 4-11. A set of center punches.

LAYING OUT STOCK

In laying out a job, an outline or pattern marked on the material shows the size and shape of the parts and the location of openings and holes. Laying out work varies, so the procedure given here may be changed to meet your particular situation. Remember when laying out stock for a project, accuracy is very important.

1. Check the end of the material from which the marking is being done to make sure it is square. Square the end if necessary.
2. Measure the stock for required length by placing a rule parallel to the edge of the stock. Check the end of the rule to be sure it is even with the square end of the stock. Make a short mark in line with the unit on the rule that represents the correct length, Fig. 4-12.

Fig. 4-12. Measuring length of stock. Mark length accurately with a scriber.

3. Mark a square line across stock at the correct length by placing a square over the stock, Fig. 4-13. The straight edge of the square head must be held firmly against the edge of the stock. Holding the scriber at a slight angle away from the blade of the square, and slanted slightly along the direction the line is to be drawn, mark a line across the stock. Cut off stock to length.
4. Prepare work for lay out of holes, cutouts, and irregular shapes by coating the surface with layout "bluing" fluid. This dries fast and provides a contrast between surface and scribed lines, Fig. 4-14.
5. Draw center lines across the length and width of the stock to serve as base lines from which all other layout lines can be accurately measured. If

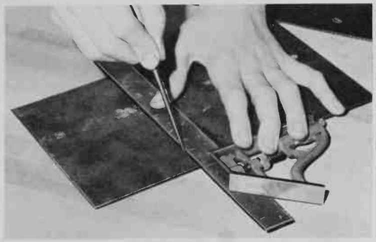


Fig. 4-13. Left. Marking a line across the stock with a combination square and a scriber. Fig. 4-14. Right. Applying layout fluid to piece of metal.

one edge of the material is even, it can be used as a base line.

6. Scribe all the straight lines first. Use center lines, or a true edge of the stock, to start all measurements.
7. Draw angular lines. Use the protractor head of the combination square set. It will be necessary to have one edge and one end true to be used as a base for the straight edge of the protractor head.
8. Draw irregular lines. Following are two methods which may be used:
   a. Use a template (pattern) of plywood or sheet metal. Place the template in place on the stock and trace around it with a scriber. This method is used when several pieces of the same shape are required.
   b. Transfer design to metal using carbon paper. Apply a coat of showcard white to metal. Place a piece of carbon paper and then the design over the metal. Trace the design with a pencil or blunt tool.
9. Scribe all arcs and circles on the metal with the dividers. To locate the center for an arc, measure in the distance required and square the lines which intersect at point A, Fig. 4-15. Make a small indentation with a prick punch where the two main lines intersect at A. Use a rule to set dividers for the required radius, Fig. 4-16. Insert

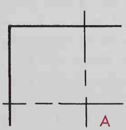


Fig. 4-15. Locating a center for laying out arcs and circles.

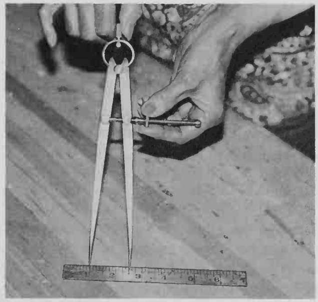


Fig. 4-16. Adjusting the dividers for a required radius.

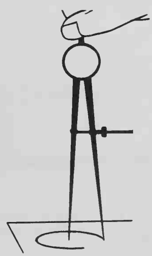


Fig. 4-17. Using the dividers to scribe a circle.

one point of the dividers in the center hole and, holding the stem by the thumb and forefinger, draw the arc or circle, Fig. 4-17.

10. Scribe lines on material to indicate all internal areas to be removed.
11. Lay out centers for holes. Locate all holes by measuring from two reference points and mark this area with two intersecting lines, Fig. 4-18. Make a small mark with a prick punch where these two lines intersect.

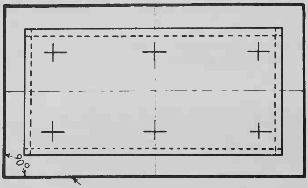


Fig. 4-18. Laying out location of holes to be drilled in stock.

CUTTING METAL

There are several tools and machines which can be used to cut ferrous and nonferrous metals. The most common tools are the hacksaw, cold chisel, bench shears, and power saw.

HAND HACKSAWS

A hacksaw has a blade, a U-shaped frame, and a handle, Fig. 4-19.

Fig. 4-19. An adjustable type hacksaw frame. (Stanley Tools)

BLADES

Hacksaw blades are made for various purposes. There is great variety in blades as to size, material and types. To make a proper choice, you should know about the following:

1. Lengths range from 8 to 12 in. General duty types are 1/2 in. wide by 0.025 in. thick; heavy duty blades are 5/8 by 0.032.
2. Material choices include high speed steel, tungsten alloy steel, molybdenum steel and other special alloy steels.
3. Flexible-backed blades with only teeth hardened are best for beginners and make good all-around blades for general sawing. All-hard type (hardened throughout the blade) are brittle and break easily.
4. Fineness is determined by teeth per inch. Range is from 14 to 32. For durability select correct blade for the job. For brass, aluminum, cast iron and soft iron, use 14 teeth to the inch; for drill rod, mild steel, tool steel and general work, 18 teeth; for tubing and pipe, 24 teeth.
5. Set of teeth refers to the way the teeth are bent to provide chip clearance. This also affects speed and ease of cutting. Fig. 4-20 shows four general types of saw sets. Wave set is used for fine-tooth blades.

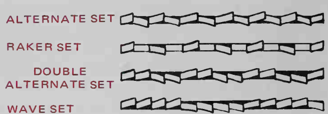


Fig. 4-20. Set of hacksaw blade teeth.

SAWING WITH HACKSAW

1. Select the correct blade. At least two teeth will be in contact with the metal at all times.
2. Fasten the blade in the frame with teeth pointing away from the handle. Tighten the blade with enough tension to hold it rigid.
3. Secure the stock in a vise, or with clamps. The cut line should be close to the end of the vise, jaw or clamp, Fig. 4-21.
4. Hold the saw at the correct angle, Fig. 4-22.
5. Start the cut with a light, steady forward stroke. At the end of each stroke, relieve the pressure and draw the blade straight back. After two or three strokes to get the cut started, take full length strokes in a straight line. Do not allow saw to wobble. Hold the saw firmly with both hands. Continue sawing, using long steady strokes at a pace of 40 to 50 strokes per minute. Use just enough pressure on the forward stroke to make each tooth remove a small amount of metal, Fig.

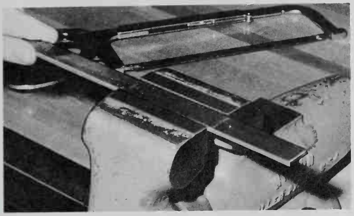


Fig. 4-21. Clamp stock tightly in vise. The line where the cut is to be made should be close to the vise jaws.

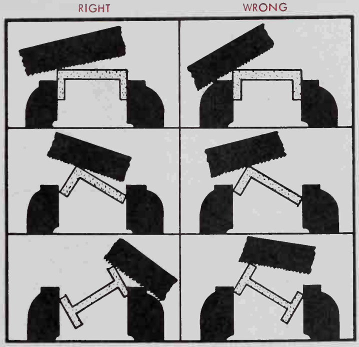


Fig. 4-22. Correct blade angle for starting cuts.

4-23. Remember--do not use any pressure on the back stroke.

6. Slow down near the end of the cut so you can control the saw when stock is sawed through.
7. To make a long cut along the side of a piece of metal, turn the blade at right angles to the frame. This makes it possible to saw a cut deeper than the saw frame would otherwise allow.

POWER HACKSAWS

The power hacksaw, Fig. 4-24, left, cuts metal bars, rods and pipe. It is efficient and easy to operate.

1. Select correct blade. Use one with four to six teeth per inch for aluminum, mild steel, brass and copper. A blade with 10 to 14 teeth per inch should be used for pipe, tubing and pieces of stock with a narrow surface. Mount the blade in the blade frame with teeth pointing in the direction of the cut. Draw blade tight in the frame.
2. Set speed. Use a slow speed for hard metals and a faster speed on soft metals.
3. Place stock in the saw vise. Leave the jaws loose until stock is adjusted. Clamp the stock firmly in the vise.
4. Adjust feed pressure by moving the weight above the saw frame. Use less pressure on soft material.
5. Start the saw and lower the blade until it begins to cut. The saw will continue the cut automatically. Apply cutting oil to the area of the cut.

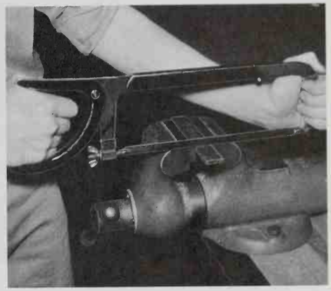


Fig. 4-23. Using hacksaw. Apply pressure on forward stroke and release pressure on return stroke.

A horizontal power saw, Fig. 4-24, right, is used in some shops. It has a continuous blade that revolves in one direction around a wheel at each end of the saw frame.

CHISELS

A chisel is a wedge-shaped tool used to shear, cut, and chip metal. It can be used in hard-to-reach places for such jobs as shearing off rivets, smoothing castings, or splitting rusted nuts from bolts. A chisel will cut any metal softer than its own cutting edge. There are four principal kinds of chisels used in bench metal work, Fig. 4-25.

1. Flat cold chisel – used for cutting, shearing, and chipping. The size is determined by the width of the cutting edge.

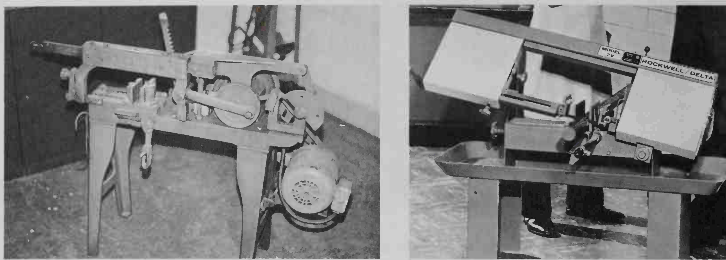


Fig. 4-24. Power hacksaws. Left. Reciprocating type. Right. Horizontal type. (Rockwell International Corp., Power Tool Div.)

2. Cape chisel – used for cutting keyways, square corners or slots.
3. Diamond point chisel – used for cutting V-grooves and inside sharp angles.
4. Round nose chisel – used to cut rounded or semi-circular grooves, corners which have fillets, and to "draw back" a drill which has "walked away" from its intended center.

You will use the flat cold chisel for most of your work. Keep your chisel sharp and ground at an angle of 60 to 70 deg. and the cutting edge at a slight arc, Fig. 4-26.

Blows of the hammer will cause the head of the chisel to mushroom. Always keep the head ground as in B, Fig. 4-27.

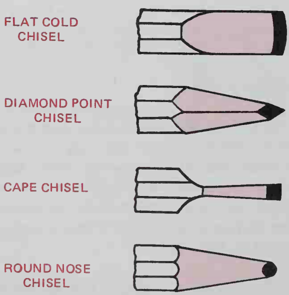


Fig. 4-25. Four kinds of chisels commonly used in metalwork.

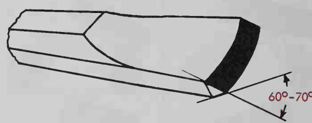


Fig. 4-26. The correct shape and point angle of a cold chisel.

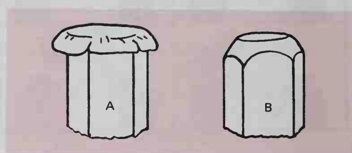


Fig. 4-27. Always keep the head of chisels ground like "B."

CUTTING METAL WITH A COLD CHISEL

Following are two methods used to cut metal with a flat cold chisel:

A. Cutting over flat plate.
   1. Scribe outline of pattern on metal.
   2. Place metal on top of a lead or soft steel back plate. Do not use finished surfaces.
   3. Grasp chisel in one hand, Fig. 4-28. Hold chisel in a perpendicular position with the cutting edge on the line to be cut.
   4. Strike the head of the chisel lightly with a ball peen hammer. Keep your eyes focused on the line to be cut, not on the chisel. Move the chisel for the next cut. Check after each

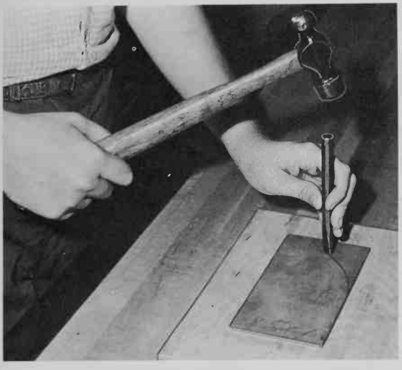


Fig. 4-28. Cutting metal with a chisel.

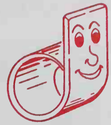
blow of the hammer to be sure the cutting edge of the chisel is on the outline to be cut.

5. Continue the light cut until you have cut around the outline.
6. Place the chisel at the starting point and cut around the outline again. Use heavier blows this time.
7. Continue cutting around outline until chisel is nearly through metal. Use lighter blows to finish cutting and to prevent cutting into the back plate.

B. Shearing in a vise.

1. Clamp the metal securely in the vise with the line to be cut slightly above the top edge of the vise jaw.
2. Place the beveled surface of the chisel's cutting edge flat on the vise jaw, Fig. 4-29.

Fig. 4-29. Shearing metal.



CHIP SAYS:

"Always wear safety glasses when cutting metal with a chisel."

The chisel will have a tendency to dig in if held too high. It will tear the metal and you will not get the proper cutting action if it is held too low.

3. Holding the chisel firmly and at an angle toward the work, direct the center of the cutting edge at the line to be cut so you will get a shearing action.
4. Start cutting at one end of the metal and strike the chisel hard enough to cut through the material. After each cut, advance the chisel until shearing is completed.

FILES

A file is a hard steel instrument made in various sizes, shapes, and cuts of teeth. Files are used for cutting, smoothing, and removing small amounts of metal. Fig. 4-30 shows the parts of a file. The three distinguishing features of files are length, kind, and cut.

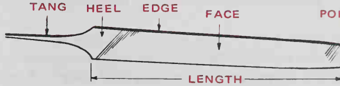


Fig. 4-30. Parts of a file.

Length: The length of the file is the distance between the heel and the point. The tang which is made to hold the handle is not included in the length.

Kind (or name): This means the various shapes or styles which are called by such names as flat, mill, half-round, etc. These are divided according to the form of their cross-sections into three general geometrical classes — quadrangular (four-sided), circular, and triangular.

The cut: This refers to the character of the teeth; such as single, double, rasp, and curved, Fig. 4-31,

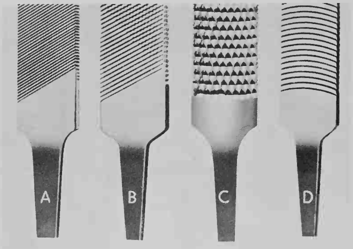


Fig. 4-31. Cuts of files: (A) Single cut; (B) Double cut; (C) Rasp cut; (D) Curved-tooth cut. (Nicholson File Co.)

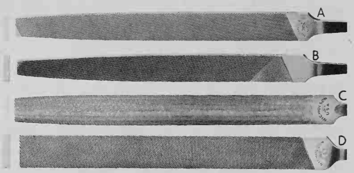


Fig. 4-32. Machinists' files: (A) Mill file; single cut, used for draw filing and finishing; (B) Flat file; double cut, for general work; (C) Half round file; double cut, used to file curved surfaces; (D) Hand bastard file; double cut, for finishing flat surfaces--it also has one safe edge (without teeth).

and also to the coarseness of the teeth; rough, coarse, bastard, second cut, smooth and dead smooth. Some machinists' files used in the metal shop are shown in Fig. 4-32.

Selecting the correct file for the work to be done is very important, in order to obtain the greatest efficiency in filing. Many factors enter into the selection of the right file for the job.

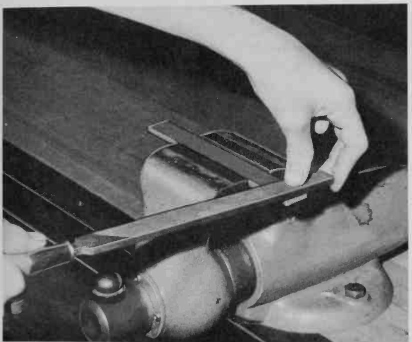
1. Size of work: Use a large file on large work and a small file for small work.
2. Flat or convex surface: Use a flat-shaped file for flat surfaces and a half-round or round-shaped file for curved surfaces.
3. Rough cutting: Use a coarse, double-cut file.
4. Square corners and enlarging square or rectangular openings: Use a square file.
5. Filing circular openings or curved surfaces: Use a round file.
6. Finishing a surface: Use a single-cut file in the second cut bastard, or a smooth file.
7. Hard steels: Use a second-cut file.
8. Soft steels; Use a bastard file.
9. Brass, aluminum, and lead: Use a special file, Fig. 4-31d.
10. Draw filing: Use a single-cut mill file.

FILING METAL

Filing is an art. The grip, pressure, and stroke must vary to fit the work being done and the kind of file used. Following are two methods for filing that you will use in bench metal work:

Straight filing. This method consists of pushing the file lengthwise--straight ahead or slightly diagonally--across the work.

1. Fasten the stock to be filed securely in a vise. The surface to be filed should be parallel to the vise jaws and a short distance above them to prevent "chattering" (excessive vibration).
2. Select the correct file for the job. For light and accurate filing, grasp the handle with one hand, allowing its end to fit into and up against the fleshy part of the palm below the joint of the little finger, with the thumb lying parallel along the top of the handle and the fingers pointing upward. Grasp the point of the file by the thumb and the first two fingers of the other hand, Fig. 4-33. For heavy work grasp the handle in the same manner just described. Place the palm of the hand on top of the point of the file with the fingers curled under, Fig. 4-34.
3. File the metal by "carrying" (stroke) the file forward on an almost straight line--changing its course often enough to prevent "grooving." A file cuts only on the forward stroke--release the pressure on the back stroke. Use a uniform stroking motion and keep the file flat on the work. Do not allow the file to "rock" as this will produce a rounded surface. Various metals require different touches, but in general, apply just enough pressure on the forward stroke to keep the file cutting at all times. If allowed to slide over hard metals the teeth will become dull.
4. Clean the file. The teeth become clogged with particles of metal. To do a good job of filing, these filings or "chips" which collect between the teeth must be removed to keep the file working efficiently and prevent the "chips" from scratching



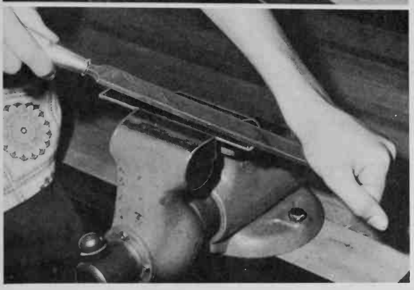


Fig. 4-33. Above. The proper way to hold a file for light filing. Fig. 4-34. Below. The proper way to hold a file for heavy filing.

your work. The teeth should be brushed frequently with a file card or brush, Fig. 4-35. Never strike your file against the bench or vise to clean it--the teeth are brittle and easily broken. When taking very fine cuts or in filing soft metals, such as copper and brass, rub the face of the file with chalk to prevent the teeth from becoming clogged.

5. Check the surfaces being filed for squareness. Hold the work up to the light and place a rule or square on the surface. If light shows between the surface being checked and the square, mark the high spots. File the high spots lightly and check again. Continue this procedure until the stock is square.
6. Remove burrs from edges. When cutting or filing heavy sheet stock, burrs form on the edges.

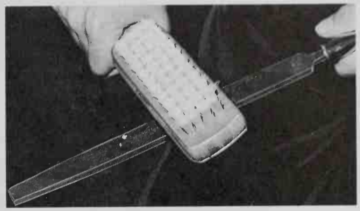


Fig. 4-35. Cleaning a file with a file card. Brush with the angle at which the teeth are cut.

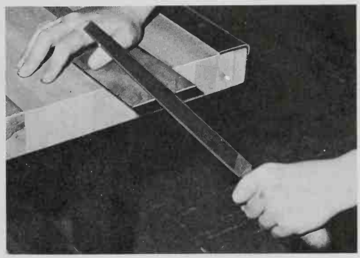


Fig. 4-36. Removing burrs from the edge of metal.

Remove these burrs by running the file across the sharp edges, Fig. 4-36.

Draw filing. This operation is performed by grasping the file at each end and pushing and drawing it across the work. A very smooth surface can be obtained by this method. Generally a mill bastard file is used for draw filing.

1. Grasp the file firmly at each end and place the file on the work at the end away from you.
2. Holding the file steady, apply sufficient pressure to get a cutting action, and draw file toward you, Fig. 4-37. At the end of each stroke lift the file and return to the starting point. Use a new section of the file for each stroke. After one side of the file has been used up turn it over and use the other side. After both sides have been used, clean the file before continuing. This is important. A chip between the teeth will scratch the filed surface.

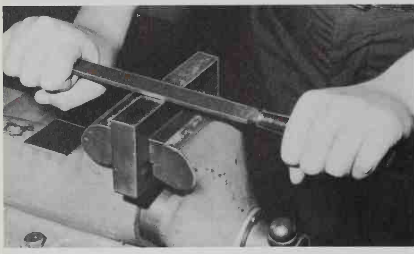


Fig. 4-37. Draw filing.

Protect your files by observing these rules:

1. Always keep a good handle on your file. The tang has a sharp point which can pierce your hand. Never use a file without a handle.
2. Never use a new file to remove scale from metal. Use an old, worn file for this job.
3. Avoid getting files oily. Oil causes a file to slide across the work and prevents fast, clean cutting.
4. Protect the file teeth. Always hang files in a rack when not in use. Never allow the teeth to come in contact with other files or tools. If you put a file in a toolbox or drawer with other tools, wrap the file with cloth.
5. Keep the file clean. Use a file card to clean the file after every few strokes. Sometimes it is necessary to use a sharp pointed nail or piece of wire to remove stubborn "chips."
6. Never use a file for prying or pounding. The body of a file is hard and very brittle. A slight bend or a fall to the floor might break the file.
7. Never hammer on a file. Since it is hard and extremely brittle the blows might cause sharp chips to fly in all directions and injure someone.

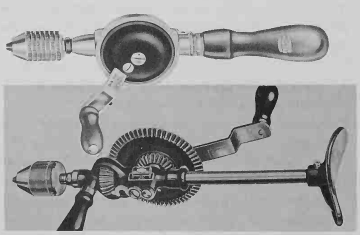


Fig. 4-38. Above. Hand drill. Below. Breast drill. (Stanley Tools)

CUTTING HOLES IN METAL

One way to produce holes in solid metal is to use a drill. Holes up to 1/2 in. in diameter can be drilled by hand with a hand or breast drill, Fig. 4-38. A portable electric drill is also a very useful and fast tool for drilling holes in metal. When drilling holes larger than 1/2 in. in diameter use a drill press, Fig. 4-39.

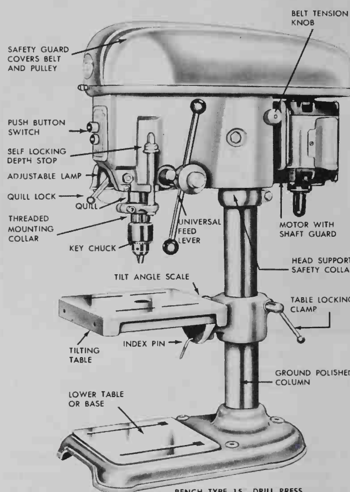


Fig. 4-39. A drill press.

The actual cutting of holes is done with a twist drill. A drill has three main parts, the shank, the body, and the point, Fig. 4-40. The shank end fits into the chuck or spindle of the drilling machine. The most commonly used twist drills are made of carbon steel and high speed alloy steel. The two types of shanks most commonly used are the straight and taper, Fig. 4-41. The body of the drill is the section

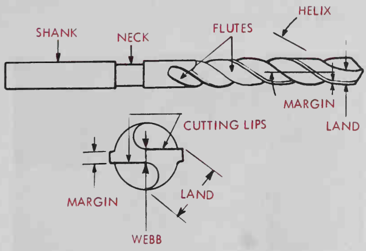


Fig. 4-40. The parts of a twist drill.

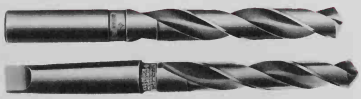


Fig. 4-41. Two types of drill shanks. Above. Straight shank. Below. Taper shank. (Cleveland Twist Drill Co.)

extending from the shank to the point. The two spiral grooves running around the body are called flutes. The point of the drill which does the cutting is the "business end" of the drill. The point is formed by the ends of the web, flutes, and margins of the drill body. The two sharp edges that do the cutting are called lips. The lips must be sharp and properly ground to do an efficient job of cutting.

The twist drills you will use most frequently are those made in fractional sizes which start at 1/64 in. and go to 1 in. in diameter. The size is stamped on the shank of the drill. If the size number has worn off the drill shank, you can check the size with a Drill Gauge, Fig. 4-42. Because these drills vary 1/64 in. from one size to the next, two other systems have been developed to provide in between sizes. Number drills range from No. 80 to No. 1, and letter drills range from A to Z. Fig. 4-43, shows these drill sizes and their decimal equivalent.

There are five things that must be checked when grinding a drill:

1. Lip angle. For most work the two lips should form an angle of 59 deg., Fig. 4-44.
2. Lip length. Both cutting edges (lips) must be the same length, Fig. 4-44. If the lips are of unequal length the drill will cut oversize.

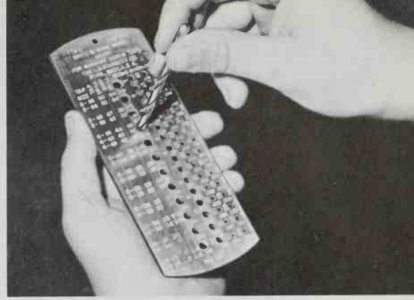


Fig. 4-42. Checking the size of a drill with a drill gauge.

Number Drills	Fractional Drills	Decimal Equiv.	Number Drills	Letter Drills	Fractional Drills	Decimal Equiv.	Letter Drills	Fractional Drills	Decimal Equiv.
80	...	.0135			1/8	.1250	O	....	.3160
79	...	.0145	30		....	.1285	P	....	.3230
	1/64	.0156	29		....	.1360		21/64	.3281
78	...	.0160	28		....	.1405	Q	....	.3320
77	...	.0180			9/64	.1406	R	....	.3390
76	...	.0200	27		....	.1440		11/32	.3437
75	...	.0210	26		....	.1470	S	....	.3480
74	...	.0225	25		....	.1495	T	....	.3580
73	...	.0240	24		....	.1520		23/64	.3594
72	...	.0250	23		....	.1540	U	....	.3680
71	...	.0260			5/32	.1562		3/8	.3750
70	...	.0280	22		....	.1570	V	....	.3770
69	...	.0292	21		....	.1590	W	....	.3860
68	...	.0310	20		....	.1610		25/64	.3906
	1/32	.0312	19		....	.1660	X	....	.3970
67	...	.0320	18		....	.1695	Y	....	.4040
66	...	.0330			11/64	.1719		13/32	.4062
65	...	.0350	17		....	.1720	Z	....	.4130
64	...	.0360	16		....	.1770		27/64	.4219
63	...	.0370	15		....	.1800		7/16	.4375
62	...	.0380	14		....	.1820		29/64	.4531
61	...	.0390	13		....	.1850		15/32	.4687
60	...	.0400			3/16	.1875		31/64	.4844
59	...	.0410	12		....	.1890		1/2	.5000
58	...	.0420	11		....	.1910		33/64	.5156
57	...	.0430	10		....	.1935		17/32	.5312
56	...	.0465	9		....	.1960		35/64	.5469
	3/64	.0469	8		....	.1990		9/16	.5625
55	...	.0520	7		....	.2010		37/64	.5781
54	...	.0550	-		13/64	.2031		19/32	.5937
53	...	.0595	6		....	.2040		39/64	.6094
	1/16	.0625	5		....	.2055		5/8	.6250
52	...	.0635	4		....	.2090		41/64	.6406
51	...	.0670	3		....	.2130		21/32	.6562
50	...	.0700			7/32	.2187		43/64	.6719
49	...	.0730	2		....	.2210		11/16	.6875
48	...	.0760	1		....	.2280		45/64	.7031
	5/64	.0781		A	....	.2340		23/32	.7187
47	...	.0785			15/64	.2344		47/64	.7344
46	...	.0810		B	....	.2380		3/4	7500
45	...	.0820		C	....	.2420		49/64	.7656
44	...	.0860		D	....	.2460		25/32	.7812
43	...	.0890		E	....	.2500		51/64	.7969
42	...	.0935			1/4	.2500		13/16	.8125
	3/32	.0937		F	....	.2570		53/64	.8281
41	...	.0960		G	....	.2610		27/32	.8437
40	...	.0980			17/64	.2656		55/64	.8594
39	...	.0995		H	....	.2660		7/8	.8750
38	...	.1015		I	....	.2720		57/64	.8906
37	...	.1040		J	....	.2770		29/32	.9062
36	...	.1065		K	....	.2810		59/64	.9219
	7/64	.1094			9/32	.2812		15/16	.9375
35	...	.1100		L	....	.2900		61/64	.9531
34	...	.1110		M	....	.2950		31/32	.9687
33	...	.1130			19/64	.2969		63/64	.9844
32	...	.1160		N	....	.3020		1	1.0000
31	...	.1200			5/16	.3125			

Fig. 4-43. Drill sizes and their decimal equivalents.

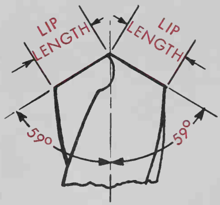


Fig. 4-44. Correctly ground drill lips.

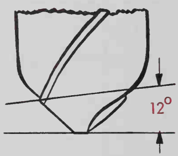


Fig. 4-45. Angle of lip clearance.

3. Lip clearance. Only the cutting edge of the two lips should contact the metal being drilled. The surface behind the cutting edge of each lip must be ground back at an angle of 12 deg. to provide proper clearance, Fig. 4-45. This angle can be increased to 15 deg. for heavy feeds in soft metals.
4. Lip sharpness. The drill will not cut properly if the lips are rounded and dull, or chipped and burned.
5. Full margin. The distance from margin-to-margin determines the diameter of the drill. If the margin is worn away or broken, the drill will heat excessively and cut a tapered, undersize hole.

PROCEDURE FOR GRINDING A DRILL

Note: Practice the first two steps without turning on the grinder to get the "feel" of the angles and movements required to grind the drill properly:

1. Hold the drill near the point with your forefinger and thumb of one hand. Cradle the drill in the first joint of your forefinger and place the back of your finger on the tool rest. Grasp the drill shank with the thumb and forefinger of your other hand. Keep the drill shank to the left, and move the point forward so that one lip comes in contact with the grinding wheel, Fig. 4-46.

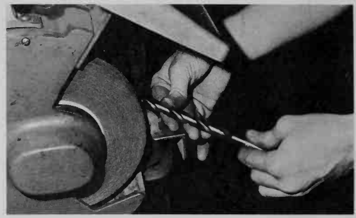


Fig. 4-46. The correct way to hold a drill for grinding.

2. Keep the shank slightly lower than the point. As the lip contacts the wheel, push down on the drill shank so that the heel (back of the lip) of the drill is moved along the grinding wheel face. When the back edge of the heel surface is reached, the drill should be pulled away from the grinding wheel.
3. After you have practiced steps 1 and 2 a few times, turn on the grinder switch. Start grinding the drill, removing very little metal at first. Try to maintain the original shape of the point. Move the drill steadily and evenly, maintaining uniform pressure against the wheel as you grind. Check your work frequently with a drill-point gauge to be sure that you have the proper lip clearance of 12 deg., the proper lip angle of 59 deg., and that the two lips are the same length, Fig. 4-47. Do not allow the drill to overheat while sharpening. Drills can be cooled in water. Cool high-speed drills in the air otherwise they might crack.

DRILLING BY HAND

The hand drill is used to drill holes 1/4 inch in diameter or smaller. Its "big brother," the breast drill, is designed for tougher jobs and will drill holes up to 1/2 inch in diameter. Following is the procedure for using hand and breast drills:

1. Center punch hole locations as indicated by the prick punch marks which were made during the layout operation, Fig. 4-48. Make the opening with the center punch large enough to receive the point of the drill.
2. Select the correct size drill. To insert drill in the chuck, grip the crank handle and body of the hand drill tightly with one hand. Use the other hand to turn the chuck shell to open the jaws wide enough to allow the drill shank you are going to use to

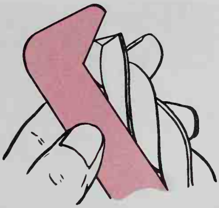


Fig. 4-47. Checking the point with a drill grinding gauge.

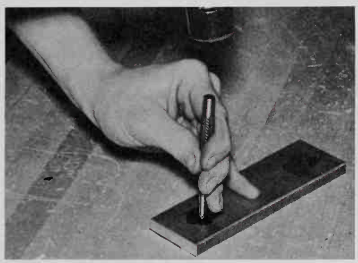


Fig. 4-48. Using a center punch.

enter. Tighten the jaws of the chuck so the drill is held firmly.

3. Secure material to be drilled in a vise or clamp it to a bench. If possible, clamp piece in a position so drilling can be done horizontally. Place the point of the drill in the center punch opening and crank drill at a moderate speed, making sure that you hold it at the proper angle with the work, usually 90 deg. Hold the drill steady, and apply enough pressure to keep the point cutting.
4. When the drill point is about to break through the metal, ease up on the pressure. Should the drill catch or jam in the material, finish cutting the hole by turning the chuck by hand. The drill should not be allowed to project through the hole any farther than is necessary to complete the hole. When the hole is completed, remove the drill. Continue to turn the drill in a clockwise direction and pull back on the handle.

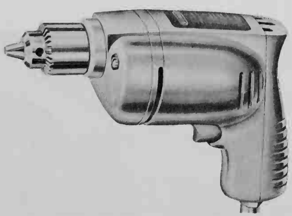


Fig. 4-49. A portable electric hand drill. (Stanley Tools)

DRILLING WITH PORTABLE POWER DRILL

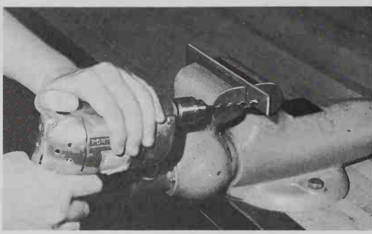
The portable electric drill, Fig. 4-49, is used the same way as a hand drill, except that you do not have to crank it. Portable electric drills vary in size. The two most common sizes have a rated capacity of 1/4 in. and 1/2 in. in steel. To drill holes with a portable electric drill:

1. Place work in a vise or clamp it to the bench. The drilling can be done either horizontally or vertically.
2. Insert proper size drill bit for the job into drill chuck. Tighten the jaws against the drill bit with the chuck key.
3. With the power off, place the point of the drill in the center punch opening.
4. Hold the drill with one hand and steady it with the other. Turn on the power and apply steady pressure, Fig. 4-50.
5. When the drill point is about to break through the material, ease up on the pressure. Remove the drill from the hole and turn off the power. Do not allow the drill bit to jerk or bind since this will probably cause it to break off.

DRILLING WITH A DRILL PRESS

The drill press automatically holds and rotates the drill bit at the proper angle with the work. Drill presses vary in sizes ranging from small bench models to huge multiple-spindle types. When you use a drill press follow this procedure:

1. Locate the center of the hole to be drilled and mark the hole with a prick punch.
2. Enlarge the hole with a center punch.



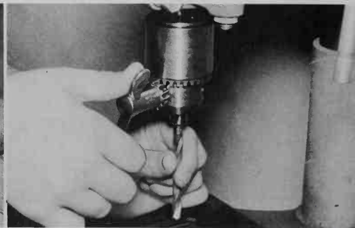


Fig. 4-50. Left. Using an electric hand drill. Fig. 4-51. Right. Inserting a drill in the drill press chuck.

3. Select the correct size drill and insert the drill in the chuck. Tighten the drill with the chuck key, Fig. 4-51.
4. Clamp the work to the table of the drill press. The type of clamp or jig used will depend on the nature of the job. Adjust the work so the point of the drill is lined up with the center mark. Place the drill press table at the correct height for the job. Check to see that the drill bit will pass through a clearance hole or slot in the table and there is no danger of drilling into the table. Fig. 4-52 shows several ways to hold metal while it is being drilled.
5. Adjust the drill press for the correct speed. The speed for drilling holes varies with the size of drill bit and material being used. The larger the drill bit, the slower the speed. A slow speed is used for hard metals and a higher speed for soft metals.
6. Turn on the power and bring the drill point down to the piece slowly. Feed the drill into the center mark with a steady, even pressure. Apply cutting fluid often enough during drilling operation to keep the drill bit lubricated and from becoming too hot.
7. Reduce the pressure slightly when the drill bit begins to go through the bottom side of the piece. This will help prevent the drill from catching.
8. When drilling holes larger than 3/8 in. it is good practice to drill a small pilot hole first. The diameter of the pilot hole, which is sometimes called a lead hole, should be approximately the size of the web thickness of the larger drill.
9. Holes which are to receive tapered heads of rivets, screws or bolts, must be countersunk. This may be done with a countersink drill, Fig. 4-53, or by using a drill bit twice the diameter of the hole.

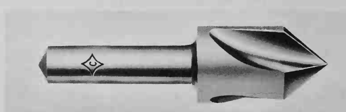


Fig. 4-53. A countersink drill.
(Cleveland Twist Drill Co.)

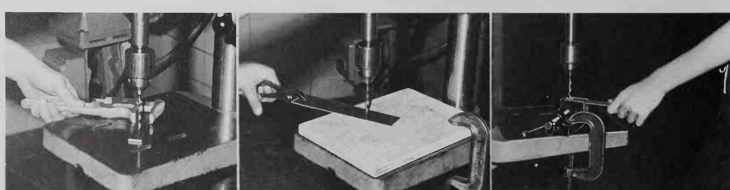


Fig. 4-52. Holding work while drilling. Left. Holding work with a monkey wrench. Center. Using a pair of pliers to hold thin stock. Right. Pieces clamped in drill press vise.

Countersink the hole enough to allow the head of the rivet, screw, or bolt to fit flush with the surface of the metal, Fig. 4-54.

Fig. 4-54. Correct and incorrect way to countersink a hole.

BENDING, FORMING, AND TWISTING METAL

Some of your projects will require the bending of metal at right angles, acute angles, and obtuse angles. Other pieces of your project may require scroll work or the twisting of some of the parts. Most of the ferrous and nonferrous metals 1/4 in. or less in thickness can be bent cold. To make angular bends follow this procedure:

1. Make a full-size layout of the part to be bent, so you can determine the amount of metal to allow for the bends. To make a right-angle bend, add an amount equal to one-half the thickness of the metal for each bend. For example, if you are using 1/8 in. thick material, and you are going to make two right-angle bends, add 1/8 in. to the length of material, Fig. 4-55.
2. When more than one bend is to be made, decide on the order of bending so you can determine where to make the allowances for bending in the layout. This is necessary because the extra amount added to the length of the material for bending should always be placed above the vise jaws when making the bend, Fig. 4-56.
3. Clamp the metal in the vise with the bend line at

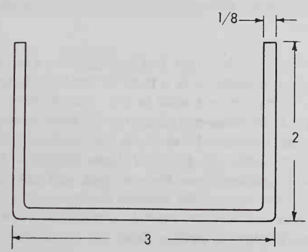


Fig. 4-55. Allow one-half the thickness of the metal for each bend.

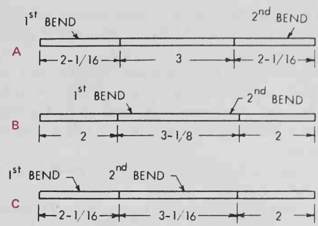


Fig. 4-56. Allowances laid out for the order of bending. The allowance has been added to the section that is to undergo the actual bending.

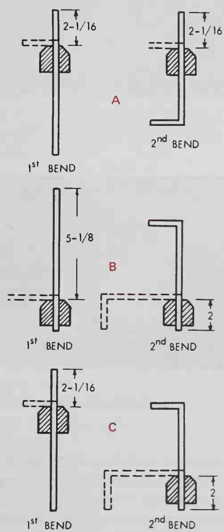


Fig. 4-57. The order of bending layouts which are shown in (A), (B), and (C), Fig. 4-56.

the top of the jaws, with the allowance end above the jaws, Fig. 4-57. Check the material with a square to make sure it is straight.

4. Bend the metal by applying pressure with one hand, and striking the metal near the jaws of the vise with a hammer at the same time, Fig. 4-58. Strike the metal just hard enough to complete the bend.
5. Check the bend with a square to make sure the bend is accurate.
6. To make a bend that is greater than 90 degrees (obtuse angle) use a monkey wrench, Fig. 4-59. It is not necessary to make any allowance for very shallow bends. If the bend is close to a right angle, an allowance should be made.

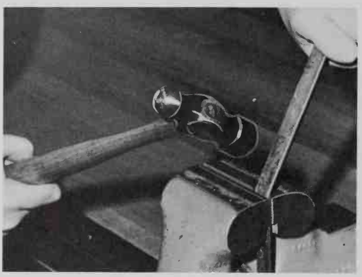


Fig. 4-58. Bending metal in a vise.

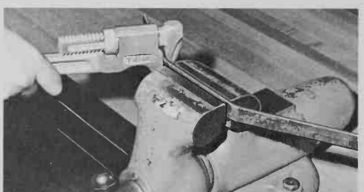


Fig. 4-59. Making a bend that is greater than 90 deg.

7. To make a bend that is less than 90 degrees (acute angle) the same allowance as made for a right angle bend must be made. Follow the procedure for making a right angle bend. To obtain the sharp angle, place the right angle bend between the jaws of the vise, and squeeze the two sides together until the correct angle is obtained, Fig. 4-60.

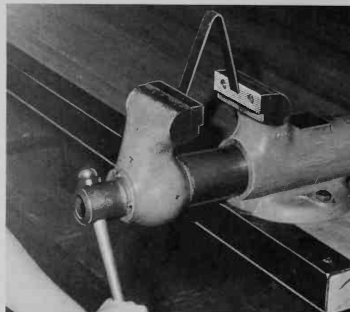


Fig. 4-60. Making a bend that is less than 90 deg.

BENDING CURVES

Many projects require circular bends. This type of bending can be done by forming the metal around a rod or pipe, or with bending and forming machines. Most metal 1/4 in. or less can be formed cold.

To form circular bends, clamp a rod or piece of pipe in a vise. Place the metal over this piece, in the vise. Strike the metal glancing blows with a ball-peen hammer, Fig. 4-61. Move the metal forward gradually, striking the metal until the desired curve is formed.

Another method that may be used when a certain radius or diameter circle is to be formed is to clamp a piece of pipe or rod equal to the inside diameter of the circle or radius in a vise, with the piece of stock to be bent clamped between the rod or pipe and the solid jaw of the vise, Fig. 4-62. Grasp the end of the stock extending above the vise jaws, and pull the metal down against the bending device. Loosen the vise jaws and feed the stock in around the rod, and clamp in place as before. Continue this procedure until the desired circle or radius has been formed. Metal that is too thick to be formed by hand can be bent around the bending device by pulling it with one

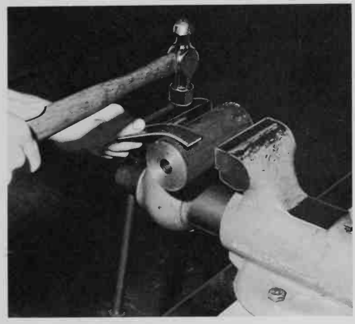


Fig. 4-61. Forming a circular bend over a rod.

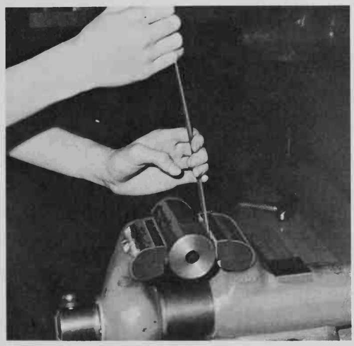


Fig. 4-62. Fasten both the rod and the work in the vise. Draw the work around the rod.

hand and striking it close to the bending device with a ball-peen hammer. Continue the bending operation by feeding the metal around the bending device and hammering it down against the bending device until the desired circle or radius is obtained.

A small eye can be formed by clamping the stock to be bent, and a piece of cylindrical pipe or rod equal to the inside diameter of the eye, in a vise. Follow the steps shown in Fig. 4-63.

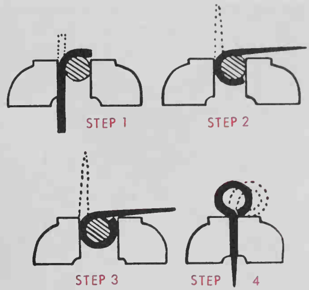


Fig. 4-63. Steps in forming an eye.

TWISTING METAL

Very interesting and pleasing lines can be added to parts of a metal project by twisting some of the pieces. Twisting is also used to give additional strength and to change the position of the piece so it can be fastened at the ends. Mild steel band iron 1/4 in. or less in thickness and 1 1/2 in. or less in width, can be bent cold. Square rods of mild steel up to 1/2 in. can be bent without heating. To bend larger sizes of stock, heat the metal to a dull red color in a forge or with a torch.

The procedure for twisting metal is:

1. Determine the portion of the stock to be twisted, and the number of desired twists. Calculate the amount of stock to allow for twisting (which tends to shorten stock) by taking a scrap piece of metal the same kind to be twisted and check the length. Make a single twist in this test piece and check the length. The difference between the length before, and after twisting, is the amount to allow for each twist to be made.
2. Mark off the section of the metal to be twisted. If duplicate pieces are to be made, mark them at the same time.
3. Place the metal to be twisted in a vise with one of the limit marks for the section to be twisted even with the outer edge of the vise jaw. Short pieces should be clamped in a vertical position, and long pieces should be clamped in a horizontal position. Clamp a monkey wrench at the other end of the section to be twisted, Fig. 4-64. The twist may be

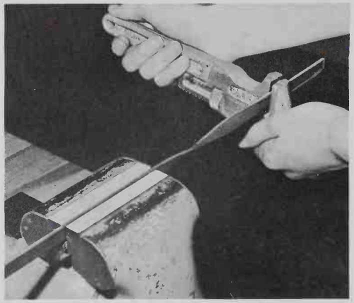


Fig. 4-64. Twisting metal with a wrench.

made to the right or left. Rotate the wrench until the desired number of twists have been obtained.

4. When twisting a long piece of metal, it is sometimes difficult to keep it straight. This can be corrected to some extent by slipping a piece of pipe which is slightly larger than the metal, over the section to be twisted.
5. If the piece of metal needs straightening after being twisted, place it over a hardwood block and hammer it with a wood or lead mallet, Fig. 4-65.

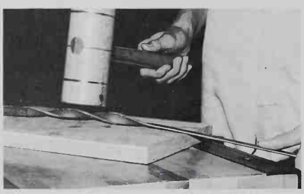


Fig. 4-65. Straightening metal after twisting.

Do not strike the metal hard enough to damage the twist. Rotate the metal as you straighten it so the portion not touching the surface of the board can be brought in line with the surface of the board. Continue this procedure until the metal is straight.

FORMING A SCROLL

A scroll is a piece of metal which has been bent to a circular shape to form a spiral similar to the shape that would be formed if a clock spring were spread open, Fig. 4-66. Scroll work is used mainly for

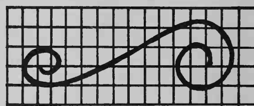


Fig. 4-66. A scroll.

decorative purposes. When properly used, scrolls break up the monotony of straight lines and add interesting features to projects. Scrolls may be formed by using jigs, forks, and other devices.

The procedure for forming a scroll is:

1. Lay out a full-size pattern of the desired scroll on a piece of heavy wrapping paper or cardboard. This pattern is used to help determine the length of stock needed and to check the work as the bending proceeds.
2. Determine the length of stock that will be needed for the scroll by forming a piece of soft wire or stock on the pattern. Then straighten the wire and measure its length.
3. Cut the stock to the correct length. Decorate the surface and the ends of the stock as desired. See Figs. 4-74 and 4-75. Select the bending device and clamp it in a vise or to a bench, Fig. 4-67.

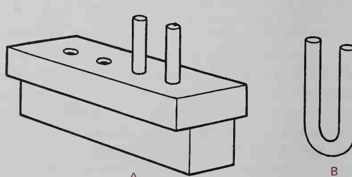


Fig. 4-67. Scroll bending devices. Left. Metal block with pins that can be adjusted for different thicknesses of metal. Right. U-shaped bending fork made from a rod.

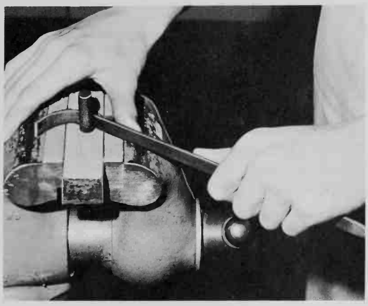


Fig. 4-68. Forming a scroll by hand.

4. Start forming the scroll by grasping the end of the metal with one hand, placing the other end in the bending device and holding it in place with the other hand, Fig. 4-68. Apply pressure with the thumb of the hand at the bending jig. Use the other hand to pull the metal against the bending jig with enough pressure to start forming the scroll. Move the metal into the jig a little at a time and continue to apply even pressure. This allows the scroll to form evenly and gradually without sharp bends. Most beginners have trouble forming scrolls without sharp bends because they try to form too much between each application of pressure. By developing a rhythm of sliding the metal through the jig (not over 1/8 in. at a time) and applying pressure to the metal at the jig each time the metal is moved forward, smooth curves can be produced without kinks. Form a small section of the scroll and check it by placing the piece on the full-size pattern, Fig. 4-69. Complete this section of the scroll to be formed. If the curve of the scroll needs to be corrected, it can be opened by placing the metal back in the jig and applying pressure in the opposite direction. Be sure to do this gradually, moving metal through the jig a little at a time. Continue to form the metal and check often until the scroll fits the pattern.

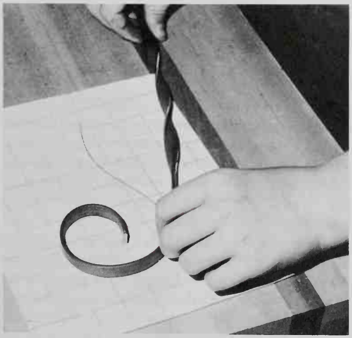


Fig. 4-69. Checking scroll on a full-size pattern.

5. When the scroll has been completely formed, check it to see if it will lie flat. If the scroll needs to be straightened, place it in a vise edgewise and straighten it by hand, Fig. 4-70.

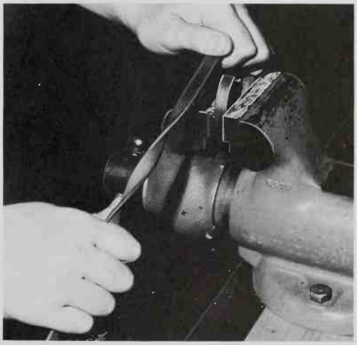


Fig. 4-70. Straigntening scroll so it will lie flat.

BENDING SMALL PIPE AND TUBING

Pipe and tubing can be formed successfully by using a jig, Fig. 4-71. If a sharp bend is necessary, fill the pipe or tubing with wet sand or molten lead. This will prevent the pipe or tubing from collapsing while being formed. Place the pipe or tubing on the jig and slowly draw it around the form. Remove the sand or lead after the desired shape has been formed.

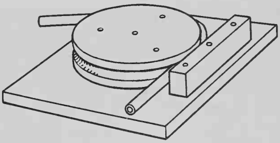


Fig. 4-71. Jig for bending pipe and tubing.

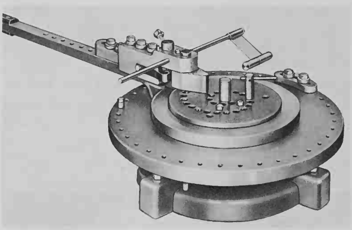


Fig. 4-72. A No. 2 Di-Acro bending machine. (Irwin O'Neil Mfg. Co.)

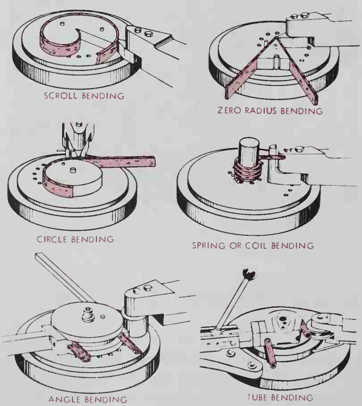
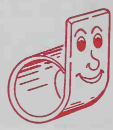


Fig. 4-73. Some bends that can be made on Di-Acro bending machine.

BENDING AND FORMING MACHINES

There are several machines available for bending and forming metal accurately and smoothly. Fig. 4-72 shows a No. 2 Di-Acro bending machine which can be used to form flats, rods, tubing, channel, and angle. Fig. 4-73 shows the bender being used to make various bends.



CHIP SAYS:

"When filling a pipe or piece of tubing with molten lead, be sure it is completely dry. Moisture causes molten metal to splatter and it might cause a serious accident."

DECORATING ENDS OF METAL

The ends of band iron can be made attractive and their appearance improved by grinding, filing, cutting, or hammering. Some possible shapes are shown in Fig. 4-74. To make a shape like (b), first lay out the

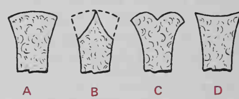


Fig. 4-74. Suggested end designs for band iron. (A) Fan shaped; (B) Arrow head; (C) Fish tail; (D) Flared.

design on the end of the metal. Spread the end of metal into a fan shape (indicated by dotted lines) by placing the end of the metal near the edge of an anvil and by striking the metal with a ball-peen hammer. Continue striking the end of the metal, working from edge to edge with closely spaced blows until the end takes a fan shape. Grind the end to a pointed shape. Finish the ground edges of the metal by hammering them down to a thin edge so the metal tapers evenly from the center of the design out to the edges and the point. If the edges of the design on the end of the metal are a little uneven, true them up with a file. Hammer the edges again with very light blows to remove any indications of file marks. In addition to the surface texture obtained with a ball-peen ham-

mer, other very interesting effects can be secured on the ends of the metal by using a cross-peen or straight-peen hammer.

DECORATING THE SURFACE OF METAL

Many interesting and decorative textures can be produced on the surface of metal by hammering it with a ball-peen, cross-peen, or straight-peen hammer. The effect can also be varied by using different size hammers and controlling the force of the blow.

To decorate the surface, mark the area of the metal to be peened or hammered. Select the hammer that will produce the desired texture, Fig. 4-75.

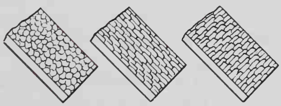


Fig. 4-75. Suggested surface decorations for band iron.

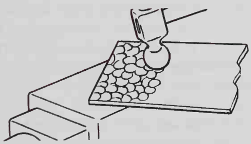


Fig. 4-76. Peening the surface of metal.

Holding the metal with one hand, place it on the surface of a flat bench plate or anvil, Fig. 4-76. Strike the metal with firm, even blows, that touch one another. Do not pound the metal so hard that it stretches. Keep the blows firm and evenly spaced, working from one edge to the other. Continue this procedure, working from one end of the metal to the other filling in the space to be decorated. The metal will probably tend to bend out of shape as you peen. To straighten the metal, place it on a flat surface and strike it with a wood mallet.

If it is necessary to decorate the other side, place a piece of soft copper on the anvil. Lay the peened side of the metal on the copper, and follow the procedure used in peening the first side. Slightly heavier blows will be necessary to obtain the same texture as that produced on the first side.

SMOOTHING METAL SURFACES WITH ABRASIVES

Metal projects are more attractive when properly finished. An appropriate finish adds to the quality of craftsmanship. To obtain a beautiful, finely polished piece of work is not difficult if a few general rules are kept in mind.

Most metals will take a fine polish if the proper abrasive is used. An abrasive is a material that cuts away other materials that are softer than itself. Abrasives may be selected from coarse grits that are fast cutting, to powders as fine as talcum that can be used for polishing.

There are two types of abrasives. Natural abrasives are found in a natural state and artificial abrasives are manufactured. Emery and corundum are commonly used natural abrasives. Emery is about 60 percent aluminum oxide and 40 percent iron oxide. Corundum is about 85 percent aluminum oxide and 15 percent iron oxide.

Artificial abrasives are more commonly used on metal. There are two principal artificial abrasives, Silicon Carbide and Aluminum Oxide. Silicon carbide is made by heating coke, sawdust, salt, and pure silica sand to a high temperature, in an electric furnace. Aluminum oxide is made from bauxite ore, similar to that used in refining aluminum. It is also made in an electric furnace.

Abrasive materials which come from the furnace are in chunk form. These chunks are crushed into small particles — grits or grains. The size of an abrasive grain is determined by the size screen they will pass through. For example, if the screen has 46 openings per inch, the grains that just pass through are size 46. Abrasive grains will range in size from 4 to 280. Abrasive flours, which are powdery fine, will range from 280 to 600.

SELECTING ABRASIVES

There are many types of abrasives which are produced for various kinds of work. The most common type used in the school shop is abrasive

cloth. This can be purchased in sheets 9 x 11 in. or in rolls 1/2 inch to 3 in. wide. For most bench metal work the following grain sizes are recommended:

No. 60 - medium coarse
No. 80 - medium
No. 120 - medium fine
No. 180 - fine

After the work has been carefully filed, a good polish can be obtained by rubbing first with No. 60, and then with No. 80 or finer. For a very high polish, use No. 120, and polish with No. 180. Abrasive cloth is used when it is not necessary to remove a quantity of metal.

When using abrasive cloth to do hand polishing follow this procedure:

1. Tear a piece of abrasive cloth from a sheet or roll.
2. Wrap it around a wood block which is long enough to grip comfortably, Fig. 4-77.
3. Apply a few drops of oil to the surface being polished. Rub the abrasive cloth back and forth. Do not allow the piece of metal with abrasive cloth to rock. Keep it flat against the surface being polished. To polish concave surfaces, wrap abrasive cloth around a rod that is smaller than the curvature of the surface. When polishing convex surfaces, use a strip of abrasive cloth and your fingers, Fig. 4-78.

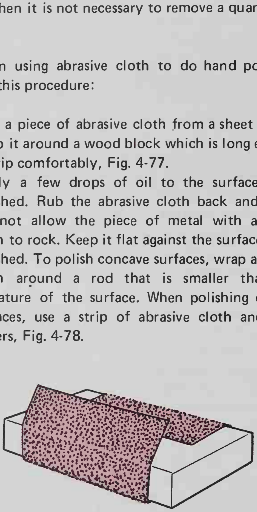


Fig. 4-77. Use abrasive cloth wrapped around a wood block to smooth flat surfaces.

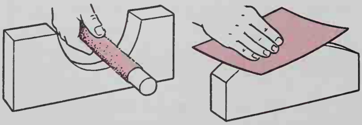


Fig. 7-78. Polishing concave and convex surfaces.

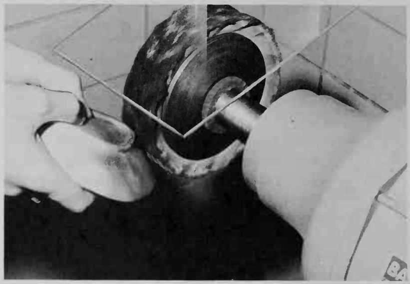
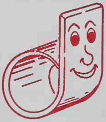


Fig. 4-79. Buffing metal.

BUFFING

Some projects in metalwork require a very highly polished surface. This can be done by using a buffing wheel and a buffing agent, Fig. 4-79. Buffing is not done until all visible tool marks and deep scratches have been removed with abrasive cloth as previously described. There are two basic types of buffing compounds: cutting compounds and burnishing compounds. Tripoli is one of the common cutting compounds that is used as a buffing agent. Tripoli is made from limestone having a high silica content. The silica grains are very soft and porous. For shop use, the powder is mixed with a grease base to form a stick or cake. Red and white rouge are two common burnishing (or coloring) compounds.



CHIP SAYS:

"Before using the buffer, remove jewelry from your fingers and wrist. Roll your sleeves above your elbows. Place a face shield or safety glasses over your eyes."

The following procedure is used for buffing metal:

1. Turn the buffer motor on and apply a stick of polishing compound lightly against the face of wheel. Hold the compound below the center of

the wheel so it will tend to pull the compound toward the machine. After the wheel has been loaded with buffing compound add more compound sparingly as needed. Too much compound on the wheel will cause it to stick and build up on the metal being buffed. A different buffing wheel should be used when changing grades of compound. Mark the buffing wheels for the grades of compounds being used so they will not get mixed.

2. Grip the work securely with both hands and press it firmly against the rotating wheel. Be sure to keep the work below the center of the wheel. Move the work back and forth across the face of wheel as you buff the surface.
3. After the polishing has been completed, wash the work with soap and hot water. Dry with a soft clean cloth. Be careful not to touch the metal with your hands.
4. To maintain a high luster, coat the work immediately with clear lacquer, plastic, or wax.

CUTTING THREADS

The cutting of threads on metal rods (called external threads) and on the interior of holes drilled in metal (called interior threads) is an important phase of metalwork. The metalworker uses threads to transmit motion, to provide for adjustments, and to fasten parts together.

The American Standard for Unified threads now in use in the United States has a basic thread angle of 60 deg. See Fig. 4-80. The crest and root may be flattened or rounded. There are two common series. The Unified Coarse (UNC) is used for general purpose work. The Unified Fine (UNF) is used for precision assemblies such as aircraft engines, automobiles and adjusting mechanisms.

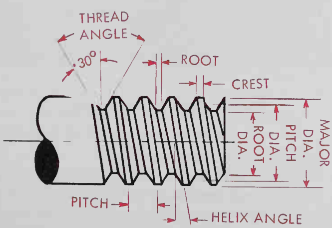


Fig. 4-80. Parts of a thread.

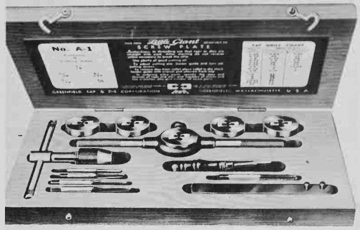


Fig. 4-81. A set of taps and dies. (Greenfield Tap and Die Corp.)

Taps and dies are the tools used for cutting threads. Taps are used for cutting threads on the interior of holes. Dies are used to cut threads on the surface of metal rods. Fig. 4-81 shows a set of taps and dies.

CUTTING INTERNAL THREADS

A tap is a piece of hardened steel which has a threaded portion for cutting threads. The shank of the tap has a square end which is gripped by the tap wrench that is used to turn the tool. Hand taps are usually provided in sets of three taps for each diameter and thread series. Each set contains a taper tap, a plug tap, and a bottoming tap, Fig. 4-82. The taper tap is used to start or cut threads completely through open holes, Fig. 48-83a. To thread a partly open hole, start with a taper tap and finish the

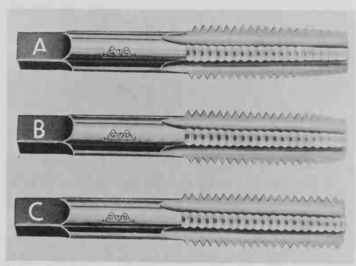
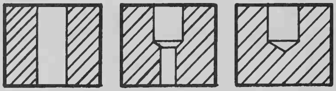


Fig. 4-82. Set of taps. (A) Taper; (B) Plug; (C) Bottoming.



(A) (B) (C)

Fig. 4-83. Kinds of holes to be threaded. (A) Open hole; (B) Partly open hole; (C) Closed hole.

threading with a plug tap, Fig. 4-83b. To cut threads to the bottom of a closed hole, start threading with the taper tap, then use the plug tap and finish threading with the bottoming tap. See Fig. 4-83c. Tap size is stamped on the shank. For example, if the tap is stamped 1/4 - 20 UNC (or NC for old National Coarse system), the thread is 1/4 in. in diameter, there are 20 threads per inch and the system is Unified Coarse.

Taps are held in tap wrenches while they are being used. There are two types. The T-handle is used for small taps. The adjustable tap wrench, Fig. 4-84, is used for larger sizes.

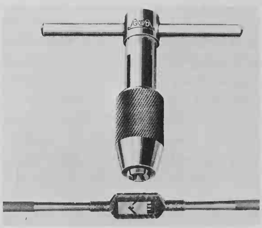


Fig. 4-84. Tap wrenches. Above. T-handle tap wrench. Below. Adjustable tap wrench.

Following is the procedure for tapping a hole:

1. Select the correct size tap with the desired number of threads per inch.
2. Select the correct size tap drill. Refer to Fig. 4-85. If the exact letter or number drill is not available, use the next larger fractional drill shown in Fig. 4-43.
3. Drill the hole carefully.
4. Secure the tap in the tap wrench. Insert the tap in the hole and start turning the tap in a clockwise direction, Fig. 4-86. Apply enough downward pressure to start the tap cutting.
5. Check the tap to see if it is starting square with the hole. Remove tap wrench and check work with a square, Fig. 4-87. If the alignment of the tap is out of square, correct the error by applying sidewise pressure as you continue turning the tap.

Size of Tap		Size of Tap Drill				Clearance Drill	
National Coarse	National Fine	Number Drills	Letter Drills	Fractional Drills	Decimal Equivalent	Drill Size	Decimal Equivalent
#4-40	.....	43	.....	.....	0.0890	#31	0.1200
	#4-48	42	.....	.....	0.0935	#31	0.1200
#5-40	.....	38	.....	.....	0.1015	#29	0.1360
	#5-44	37	.....	.....	0.1040	#29	0.1360
#6-32	.....	36	.....	.....	0.1065	#25	0.1495
	#6-40	33	.....	.....	0.1130	#25	0.1495
#8-32	.....	29	.....	.....	0.1360	#16	0.1770
	#8-36	29	.....	.....	0.1360	#16	0.1770
#10-24	.....	25	.....	.....	0.1495	13/64	0.2031
	#10-32	21	.....	.....	0.1590	13/64	0.2031
#12-24	.....	16	.....	.....	0.1770	7/32	0.2187
	#12-28	14	.....	.....	0.1820	7/32	0.2187
1/4"-20	.....	7	.....	.....	0.2010	17/64	0.2656
	1/4"-28	3	.....	.....	0.2130	17/64	0.2656
5/16"-18	.....	...	F	.....	0.2570	21/64	0.3281
	5/16"-24	...	I	.....	0.2720	21/64	0.3281
3/8"-16	.....	...	.....	5/16	0.3125	25/64	0.3906
	3/8"-24	...	Q	.....	0.3320	25/64	0.3906
7/16"-14	.....	...	U	.....	0.3680	29/64	0.4531
	7/16"-20	...	.....	25/64	0.3906	29/64	0.4531
1/2"-13	.....	...	.....	27/64	0.4219	33/64	0.5156
	1/2"-20	...	.....	29/64	0.4531	33/64	0.5156
9/16"-12	.....	...	.....	31/64	0.4844	37/64	0.5781
	9/16"-18	...	.....	33/64	0.5156	37/64	0.5781
5/8"-11	.....	...	.....	17/32	0.5312	41/64	0.6406
	5/8"-18	...	.....	37/64	0.5781	41/64	0.6406
3/4"-10	.....	...	.....	21/32	0.6562	49/64	0.7656
	3/4"-16	...	.....	11/16	0.6875	49/64	0.7656
7/8"-9	.....	...	.....	49/64	0.7656	57/64	0.8906
	7/8"-14	...	.....	13/16	0.8125	57/64	0.8906
1"-8	.....	...	.....	7/8	0.8750	1 1/64	1.0156
	1"-14	...	.....	15/16	0.9375	1 1/64	1.0156

Fig. 4-85. Tap drill sizes.

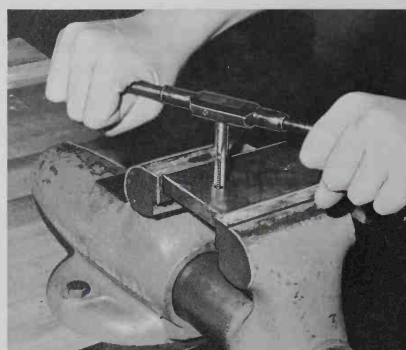


Fig. 4-86. Cutting internal threads.

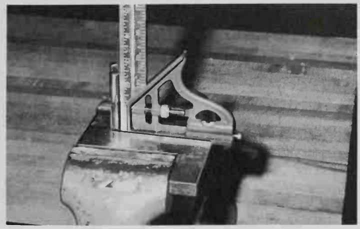


Fig. 4-87. Checking a tap after it is started to make sure it is square with the piece.

6. If the hole is being tapped in steel apply a lubricant. Lard oil can be used. Cast iron is tapped dry.
7. Turn the tap forward about one-half turn, then back it up until you feel the chips break loose. Repeat this procedure until threading has been completed. When tapping cast iron the tap should not be backed but you should continue forward until threading is completed. CAUTION: Be careful not to force tap if it gets stuck. Taps are very brittle and will break easily. Gently move the tap back and forth until it loosens.
8. Remove the tap by backing it out carefully. If it gets stuck, work it back and forth gently to loosen.

When cutting threads in a partly open or closed hole, be very careful as the tap comes close to the bottom of the hole. Remove the tap and clean out the chips often, so the tap can reach the bottom of the hole.

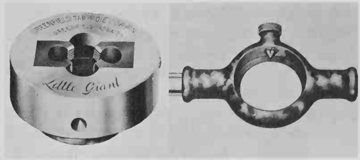


Fig. 4-88. Left. Die. Right. Die stock. (Greenfield Tap and Die Corp.)

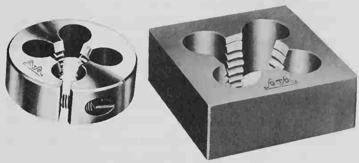


Fig. 4-89. Left. Adjustable die. Right. Solid die.

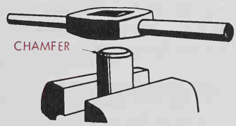


Fig. 4-90. Die will start more easily if the end is chamfered.

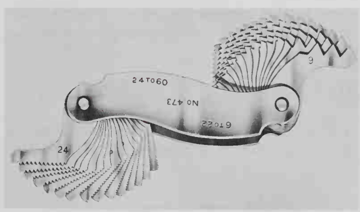


Fig. 4-91. A screw pitch gage. (L. S. Starrett Co.)

CUTTING EXTERNAL THREADS

External threads are cut by hand with a die held in a die stock, Fig. 4-88. The die cuts threads on the external surface of rods and bolts that will fit into standard-size nuts, tapped holes, or fittings. Some dies are adjustable while others are solid dies which are not adjustable, Fig. 4-89. Following is the procedure for cutting external threads:

1. Chamfer the end of the stock, Fig. 4-90. The chamfer can be cut with a file or on a grinder.
2. Select the correct size for the diameter of the rod to be threaded. A UNC or UNF die can be used. When the number of threads per inch is not known, use a screw pitch gage, Fig. 4-91. This gage contains several thin blades which have saw like teeth on them. To use the gage, try blades

until one is found that fits the threads to be duplicated. The number of threads per inch is stamped on the blades.

3. Place the die in the die stock. Tighten the setscrews in the die stock, so the die is held firmly in place. If the die is adjustable, set it to cut oversize threads first. You can always make the threads smaller but you cannot make them larger. A tap is not adjustable, so it is better to tap first, then cut the external threads to fit the tapped hole.
4. Fasten the work firmly in a vise in a vertical or horizontal position.
5. Place the die over the end of work. Die threads are tapered. Be sure the tapered side starts the cut. Reverse the die only when it is necessary to cut full threads up to a square shoulder.
6. Start cutting the threads by turning the die stock clockwise and applying downward pressure. Be careful to start the threads straight and keep them straight. Add a little cutting oil when threading steel. Back up the die occasionally to break the chips loose. Continue until threading is completed.
7. Check the threaded work to see if it fits the tapped hole or nut. If the threads are too tight, adjust the die to take a little deeper cut and run the die over the threaded section again.

METAL FASTENING DEVICES

Fastening devices are used to hold pieces of a project together. The type, shape, and size of fastening devices to be used depend upon the nature of the work. For example, rivets are used to hold pieces together permanently. Bolts or screws are used when the pieces may be disassembled occasionally or have to be adjusted.

RIVETING

Rivets can be used for ornamentation as well as fastening pieces of metal together. Soft iron rivets are used for wrought iron projects. They are available in round, oval, flat, and countersunk heads, Fig. 4-92. The most common size rivets used are 1/8 and 3/16 in. in diameter and 1 in. long. Projects made of aluminum, copper, or brass may be fastened together with rivets made of the same material, or contrasting metal. The most common size nonferrous rivets are 1/16 and 1/8 in. in diameter with round heads. The procedure for riveting is as follows:

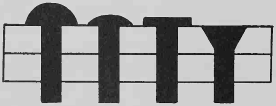


Fig. 4-92. Common rivet shapes.

1. Select the correct size and shape rivets. Use a flat-head rivet if it is not to be noticeable. Round-head rivets are used if they are to be part of the design. The rivets must be long enough to go through both pieces of metal and extend beyond by one and one-half times the diameter if the head is to be rounded on both sides. If the rivet is to be flush, allow just enough material to stick through to fill the countersunk hole.
2. Locate and drill the holes. Countersink the hole if the rivet is to be flush with the surface. If several rivets are to be used, drill only one hole and finish the riveting process before drilling the other holes. This procedure makes it easier to line up the remaining holes when joining two pieces.
3. Insert the rivet in the hole, and place the head against a solid piece of material. The heads of countersunk rivets should be set on an anvil or block of iron, and round-head rivets should rest in a cup-shaped hole so the shape of the head will not be damaged, Fig. 4-93. To rivet scroll work, place the piece to be riveted over a steel rod fastened in a vise or to a bench, Fig. 4-94.

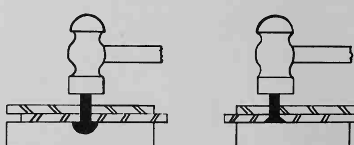


Fig. 4-93. Use a riveting plate or riveting set to protect the heat of the rivet.

4. Upset the rivet by striking the end with the flat face of the ball-peen hammer, Fig. 4-95. This causes the rivet to expand and fill up the holes. If the rivet is to be formed, shape the flattened end of rivet by striking it with the peen end of the hammer. If the back of the rivet is to be flat, strike

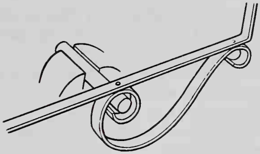


Fig. 4-94. A rod fastened in a vise can be used to rivet scroll work.

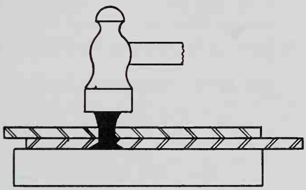


Fig. 4-95. Upsetting a rivet.

it with the peen end of the hammer to fill countersunk hole. Then finish operation by striking with the flat face of the hammer.

MACHINE SCREWS

Machine screws are used in tapped holes for the assembly of metal parts. Sometimes machine screws are used with nuts. Most machine screws are made of steel or brass. They can be purchased in a variety of diameters, lengths, and head shapes. Here is a typical example of how to give the specifications for a machine screw: 1 inch (length), 6-32 (thread-diameter), round head (head shape), steel (material). 6-32 means that the screw gauge is No. 6, and that it has 32 threads per inch. Most of the time you will use the common types of machine screws shown in Fig. 4-96.

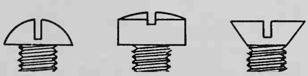


Fig. 4-96. Common types of machine screws.

Square or hex nuts can be used on machine screws. The head of a machine screw may be specified either slotted, for use with a plain screwdriver, or with a Phillips head for use with a special Phillips screwdriver.

STOVE BOLTS

Stove bolts were developed for use on stoves as the name suggests. They are used for many other jobs where accuracy and strength are not required. Stove bolts have coarse threads that make a loose fit with the threads of the square nut. Stove bolts can be purchased with flat heads, round heads, or oval heads.

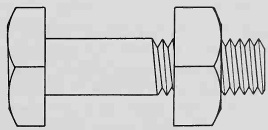


Fig. 4-97. Machine bolt.

MACHINE BOLTS

Machine bolts are made with square or hexagonal heads, and the nuts may also be of either type, Fig. 4-97. They may be purchased in a variety of diameters, lengths, and standard UNC or UNF threads. They can be furnished in three grades—rough, semifinished, or machine-finished.

NUTS

Square and hexagonal nuts are standard, but there are also many special nuts available, Fig. 4-98. One of

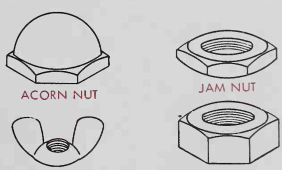


Fig. 4-98. Nuts.

these is the wing nut which is used where frequent adjustment is necessary. Cap, or acorn nuts are used when appearance is important. A jam nut is used on top of a standard hexagonal nut to lock it in position.

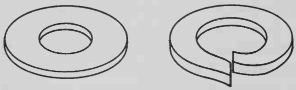


Fig. 4-99. Two common types of washers.

WASHERS

There are two common types of washers, the flat and the split lock, Fig. 4-99. Flat washers serve the function of providing larger bearing surfaces and preventing damage to the surfaces of the metal parts through which a bolt passes. Split lock washers are used under nuts to prevent them from loosening by vibration.

QUIZ – UNIT 4

1. Why is bench metal basic to all other areas of metalwork?
2. List four things a combination square can be used for in metalwork.
3. How can the surface of a piece of metal be prepared so scribed lines may be seen more clearly?
4. How many hacksaw teeth should be in contact with the metal when cutting?
5. What is a cold chisel used for?
6. Which method of filing should be used to obtain a smooth surface?
7. Name three systems used to designate the size of drills.
8. When drilling holes larger than 3/8 in. it is good practice to drill a _______ first.
9. If you are using 1/8 in. thick band iron and you are going to make two right angle bends, how much should be added to the length of the stock?
10. If a piece of pipe requires a sharp bend it should be filled with _______ or _______.
11. What is the difference between natural and artificial abrasives?
12. Which abrasive is the finest, No. 80 or No. 120?
13. Tripoli is a cutting compound that is used as a _______.
14. The American Standard for Unified threads has a basic thread angle of _________ deg.
15. Internal threads can be cut by hand with a hand _______.
16. What is the difference between the tap drill size and the clearance drill size?
17. External threads can be cut by hand with a _______.
18. List four metal-fastening devices.

Industry provides many careers from the semi-skilled to the highly skilled sheet metal trades. The machine on the right side of the picture is a 600 ton stamping press. This company manufactures heating and air conditioner components. (Lennox Industries)

Unit 5
SHEET METAL

After studying this unit, you will know:
1. **Information about the sheet metal industry.**
2. **How to use sheet metal tools and machines.**
3. **How to fabricate sheet metal projects.**

THE FIELD OF SHEET METAL WORK

This area of metalworking is concerned mostly with the building trades. It includes the installation of heating and air conditioning systems, roof work, and metal trim. Sheet metal work is also required in manufacturing automobiles, rockets, railroad cars, ships, airplanes, metal furniture, and household appliances.

In this area of metalwork you will learn to cut, form, shape, and assemble sheet metal stock. You will learn to make such items as boxes, pans, funnels, mailboxes, and canister sets. Most craftworkers find sheet metal work very interesting. It is also a fascinating hobby. Some of the fundamentals you studied in Unit 4 will be used in this unit.

CAREER OPPORTUNITIES

The sheet metal field and its related areas of work employ several million metalworkers. People employed in the sheet metal trades work mostly with sheet metal stock (black and galvanized), tin plate, copper, brass, and aluminum. They use sheets of metal ranging from a few thousandths to one inch or more in thickness. The sheet metal industry and those who work in it contribute much to make life more comfortable and enjoyable.

Sheet metal workers lay out and plan each job. They determine the size and type of metal to be used and methods of fabrication. Sheet metal workers must be able to use hand snips, power driven shears and other types of cutting tools with accuracy. They shape the metal with a variety of hammers, anvils and machines. The skilled person in the sheet metal field of work also must know how to weld, bolt, rivet, solder or cement seams and joints. Some workers specialize in shopwork or on-site installation work. However, the skilled sheet metal worker must be able to perform all of the operations required.

LAYING OUT AND DEVELOPING PATTERNS

Before constructing a sheet metal project it is necessary to first develop a stretchout (pattern) either on a sheet of paper, or on the metal. The inexperienced sheet metal worker should draw the pattern on paper first so it can be checked to see if any mistakes have been made. The pattern is then transferred to the metal by scribing the lines directly on the metal. Use a pencil if a scriber mark is objectionable. If several pieces of the same kind are to be made and especially where irregular curves are involved, a metal template is used. This template is placed on the metal and a scriber is used to trace around the outside.

Many sheet metal articles require developments. The three kinds of pattern development include: Parallel-line development, as shown in Fig. 5-1,

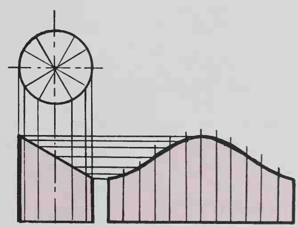
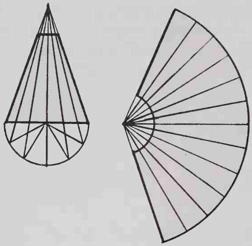


Fig. 5-1. Parallel-line development. This kind of pattern development may be used to lay out a scoop.



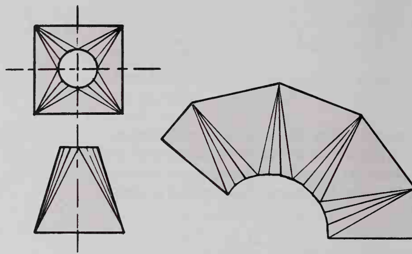


Fig. 5-2. Left. Radial-line development that might be used for a funnel. Fig. 5-3. Right. A combination of parallel-line and radial-line development. This kind of pattern development is used when it is necessary to go from square to round, as in heating and ventilating duct work.

Radial-line development, Fig. 5-2, and a combination of Parallel-line and Radial-line development, Fig. 5-3. The latter of these includes triangles as well as cones and cylinders, and is sometimes referred to as triangulation. Unit 11 in the Build-A-Course Series on Drafting explains sheet metal patterns.

SELECTING SHEET METAL

The most common types of sheet metal used in school shops are tin plate, mild steel coated with tin; galvanized steel, mild steel coated with zinc; cold finished steel sheet; aluminum, pure or alloyed; brass, alloyed copper and zinc and copper which is pure metal.

Sheet metal is available in various sizes and thicknesses. Thickness is measured with a sheet metal gauge. Tin plate, galvanized steel and cold finished steel are measured with a U.S. Standard Gauge. Aluminum, brass and copper are measured with a Brown and Sharpe or American Standard wire gauge, Fig. 5-4.

To use these gauges, remove burrs on the edges of the metal. Insert the sheet metal into the slots of the gauge until you find the one that fits. The number stamped at the opening is the gauge size of the material.

CUTTING SHEET METAL

Sheet metal 18 ga. or thinner can be cut with bench shears. Standard tinner's snips will cut up to 22

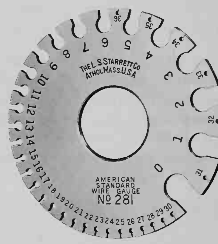


Fig. 5-4. Wire gauge measures thickness of sheet metal. (American Standard)

ga. Other snips are designed for special purpose. Straight snips are for cutting straight lines and large outside curves, Aviation snips are very useful for cutting compound curves and intricate designs. Both types are shown in Fig. 5-5. Aviation snips have variations for cutting right or left hand curves and one which cuts either way. Hawk-billed snips have narrow, curved blades for curved cuts.

Never cut with the full length of the blades. If blades are completely closed, points will tear the metal. Stop each cut about 1/4 in. from the end of the blades. Cut to the right of the layout line when possible. When cutting outside curves, first rough out leaving about 1/8 in. beyond layout line. Finish by

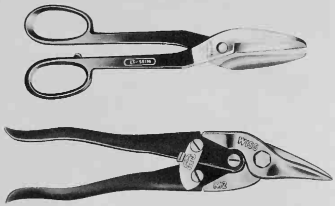


Fig. 5-5. Sheet metal snips. Above. Straight snips. Below. Aviation snips, right cut.

carefully cutting around layout line, Fig. 5-6. To cut inside curves, first punch or drill a hole in the waste stock to allow the blades of the hawk-bill snips to get started. Insert the snips from the underside of stock and rough cut the inside opening to about 1/4 in. of the layout line. Then trim the hole to size, Fig. 5-7.

When the snip blades become dull, they can be sharpened by grinding. Take the two blades apart and grind them to an included angle of 85 deg. Put the blades together again and adjust the blade tension by turning the nut on the pivot bolt or pin. The blades should be just tight enough to remain in any position in which you open them. Keep the pivot well oiled. Keep the blades closed when the snips are not being used. Remember snips are sheet metal tools and should not be used to cut wires, bolts, rivets, or nails.

Electric portable shears are very handy for cutting sheet metal which is 18 ga. or lighter, Fig. 5-8. This machine can be used to make both straight and

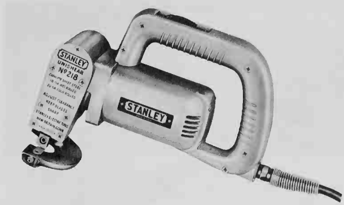
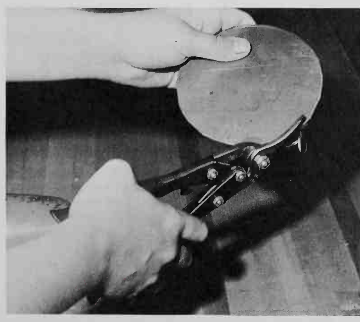


Fig. 5-8. Electric portable shears.

curved cuts. It will cut a minimum radius of about 1 in. To use the shears, place the metal between the cutters. Turn on the switch and guide the cutters along the line to be cut.

Some shops are equipped with squaring shears, Fig. 5-9. This machine can be used to trim and square sheet metal 18 ga. or lighter. The size of the machine is determined by the width of material it will cut. The common sizes are 30 or 36 in. To use the machine set the back gage at the rear of the shears, to cut material to the desired length. Insert the material from the front and hold it firmly against the side and rear



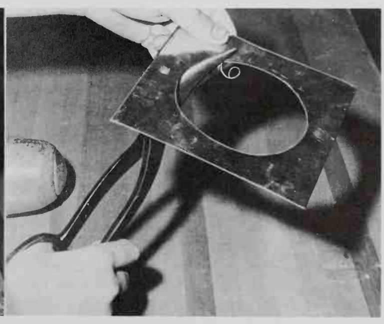


Fig. 5-6. Left. Cutting on outside curve with aviation snips. Fig. 5-7. Right, Cutting on inside opening with hawk-bill snips.

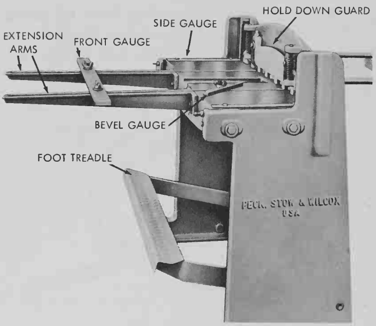


Fig. 5-9. Squaring shears. (Peck, Stow & Wilcox Co.)

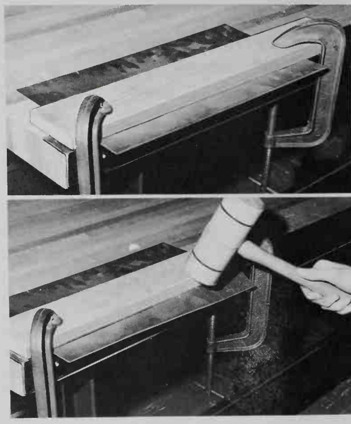


Fig. 5-10. Above. Metal clamped to bench for bending. Below. Bend the metal gradually working back and forth across the metal.

gages. Press down on the treadle with your foot. This moves the cutting blade to make the cut.

When the work is inserted from the back, use the front gage to control the length of cut. The side gage should be kept at right angles to cutting blade.

BENDING SHEET METAL

Sheet metal can be bent by hand or with a machine. A skilled worker should know how to bend sheet metal by hand because machinery is not always available. Also, there are occasions where a machine does not have the necessary capacity.

BENDING BY HAND

To make angular bends by hand, clamp two pieces of hardwood or angle iron in a vise, with the sheet metal between them. If the metal is too large to fit in the vise, use two C clamps, Fig. 5-10. The line where the metal is to be bent, should be even with the upper edge of the jig. To bend the metal down, start by striking light blows with a mallet at one end and work along the full length of the stock. Continue working back and forth making a gradual bend.

There are several sheet metal stakes which can be used for many bending and forming operations, Fig. 5-11. A hatchet stake can be used to make a sharp angle bend. To bend metal this way, place the bend line of the piece over the sharp edge of the stake. Then press the metal down with your hands, Fig.

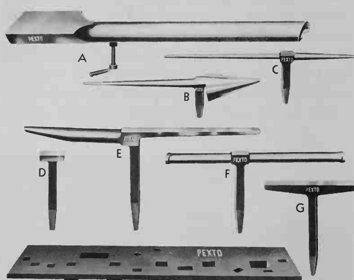


Fig. 5-11. Sheet metal stakes: (A) hollow mandrel; (B) blowhorn; (C) candle mould; (D) common square; (E) breakhorn; (F) double seaming; (G) hatchet; (H) stake plate. (Peck, Stow & Wilcox Co.)

5-12a. Square up bend with a wood mallet, as shown in Fig. 5-12b.

To bend a box by hand, first clamp the metal as shown in Fig. 5-13a. Bend the hem at a right angle. Release the clamps and remove the metal. Clamp the

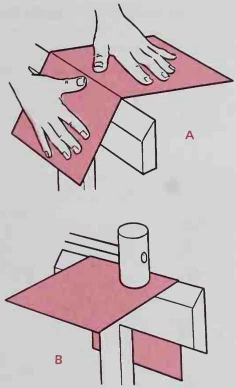


Fig. 5-12. Making a sharp bend over a hatchet stake.

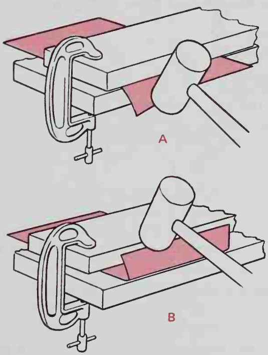


Fig. 5-13. Bending a hem between two boards.

metal on the edge of a bench with the partially turned hem up, Fig. 5-13b. Close the hem with a mallet and a block of wood Fig. 5-14. A short hem can be made with a hand seamer, Fig. 5-15. First, adjust the hand seamer for the size hem to be bent by setting the knurled screws at the proper distance and clamp them in place with the locking nut. Press the

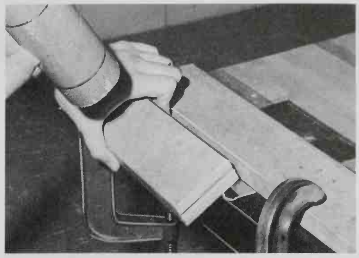


Fig. 5-14. Closing a hem with a mallet and block of wood.

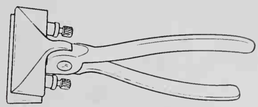
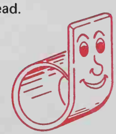


Fig. 5-15. A hand seamer.

piece against the top surface of a bench with one hand and grip the metal with the hand seamer. Squeeze the handles of the hand seamer so the jaws will not slip off the metal. Bend the hem as far as the seamer will allow it to go. Open the seamer and squeeze the metal to close the hem.

After the hems have been bent by one of the described methods, bend the two ends of the box by using clamps and two pieces of wood. Next, cut a block of wood the exact size of the bottom of the box. Clamp this block in position as shown in Fig. 5-16. Then bend up the sides of the box. Draw the metal tightly against the wood block by striking it with light blows near the bend with a mallet. Work back and forth across the full length of the bend. Be careful not to dent the metal with the edge of the mallet head.



CHIP SAYS:

"When using Squaring Shears, keep your fingers away from the cutting blade at all times. When it is necessary to have a helper, warn of the danger of getting a foot under the treadle or hands near the cutting blade."

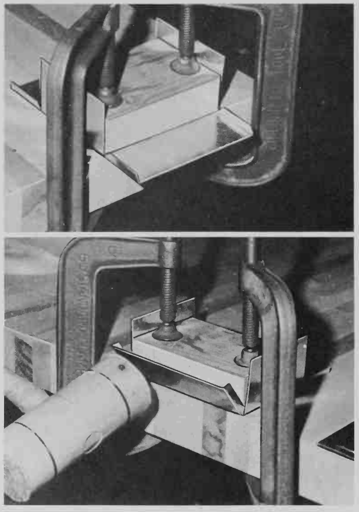


Fig. 5-16. Bending up the sides of a box by hand. Above. Metal clamped in position for bending. Below. Drawing the metal tightly against the block of wood with a mallet.

BENDING CYLINDRICAL FORMS BY HAND

A cylindrical piece may be formed to shape by bending it around a stake, rod, or pipe which is slightly smaller or equal to the diameter to be bent. Light-weight metal can be formed around the stake by hand, Fig. 5-17. To form heavier weights, hold the metal on top of a stake with one hand, then strike it glancing blows with a mallet as you feed the piece across the stake, Fig. 5-18. Continue this procedure until the metal has been formed to the desired shape.

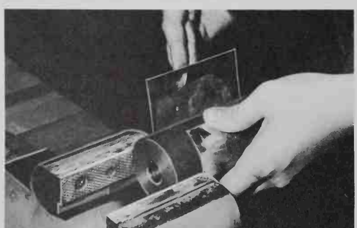


Fig. 5-17. Forming light weight metal around a rod by hand.

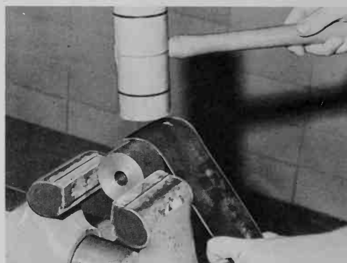


Fig. 5-18. Forming heavier weight metal around a rod with a mallet.

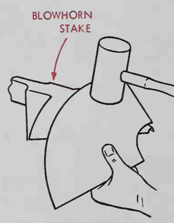


Fig. 5-19. Forming metal over a blowhorn stake.

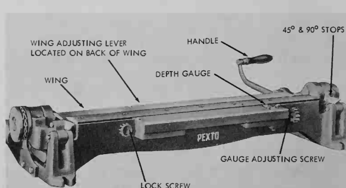


Fig. 5-20. A bar folder. (Peck, Stow & Wilcox Co.)

FORMING CONE-SHAPED ARTICLES

Cone-shaped pieces such as funnels and spouts should be formed on a tapered stake. A funnel, for example, can be formed over the apron of a blowhorn stake, Fig. 5-19. When the gage of the metal is too heavy to form by hand use a mallet.

BENDING METAL ON A BAR FOLDER

The bar folder is a folding machine which comes in various sizes, the most common of which has a folding length of 30 in. Fig. 5-20. These machines will fold an edge as narrow as 1/8 to 1 in. on metal as heavy as 24 gage. A 3/16 in. fold is the narrowest bend practicable when using 22 ga. metal.

The bar folder is used for making single or double hems, a sharp or open lock, turning an edge to receive a wire, and turning flanges, Fig. 5-21. To perform

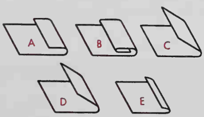


Fig. 5-21. Common hems that can be turned on the bar folder: (A) single hem; (B) double hem; (C) sharp lock; (D) open lock; (E) turned edge to receive a wire.

these operations there are two adjustments to make. The depth of the fold which is controlled by turning the gage-adjusting screw knob in or out, and the sharpness of the fold which is obtained by adjusting the wing. There are two angle stops at the left end of the bar folder. By setting the appropriate angle stop in place the fold may be stopped at 45 or 90 deg. The fold can be stopped at any desired angle from 10 to 120 deg. by setting the adjustable stop at the handle end of the machine.

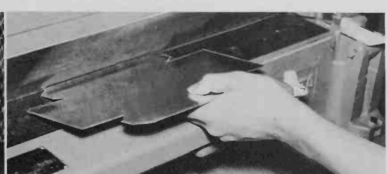
In preparing to use the bar folder, check the edge of the metal to be folded to be sure it is straight, then follow this procedure:

1. Loosen the locking screw, then turn the gage-adjusting screw until the machine is set to make a fold of the desired width. Tighten the locking screw to hold this adjustment.
2. Loosen the wedge screw on the folding bar and position the wing with the wing-adjusting lever to make an open or closed lock as desired. Tighten the wedge screw to hold this adjustment. When making an open lock for wired edges, set the wing adjusting lever so the distance between the wing and the edge of the folding blade is equal to the diameter of the wire plus about 1/32 in. Set the gage to make a fold equal to one and one-half times the wire diameter.
3. Place the edge of the metal in the folder and hold it against the gage tightly. Then pull the handle toward you until the fold is completed, Fig. 5-22. Do not release your grip on the handle until it is in its original position.
4. Return the handle to starting position. Remove the folded metal.
5. If a hem is being made, place the metal on the beveled part of the blade with the fold upward, and set tightly against the wing of the folder, Fig. 5-23. Pull the handle to flatten the fold. Return the handle to its original position, and remove the metal.

BENDING METAL ON A BOX AND PAN BRAKE

The Box and Pan Brake is an ideal machine for bending metal boxes and pans of a size within its limits, Fig. 5-24. Most box and pan brakes found in school shops will bend metal up to 24 in. long, and 16 ga. in thickness. The upper jaw is made up of removable fingers which are of various widths. To bend a box on this machine, fold the hems first. Then fold the two sides at 90 deg. To bend the two ends,

Fig. 5-22. Left. Folding metal in the bar folder. Fig. 5-23. Right. Closing a hem on the bar folder.



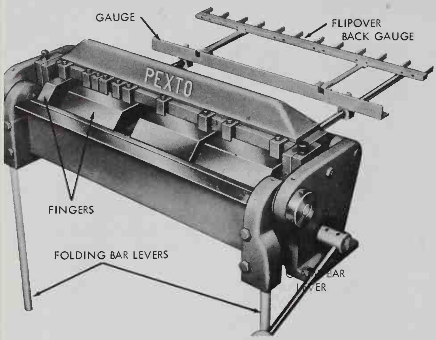


Fig. 5-24. A box and pan brake.

set up the machine with just enough fingers to equal the width of the box. Bend the two ends. Many shapes can be bent on a Box and Pan Brake.

FORMING METAL ON A FORMING MACHINE

The forming machine, or rolls, as they are more commonly called, are used for curving sheet metal and forming cylinders of various diameters. The most common forming machines have rolls that are 30 to 36 in. wide and 2 in. in diameter, Fig. 5-25. They can

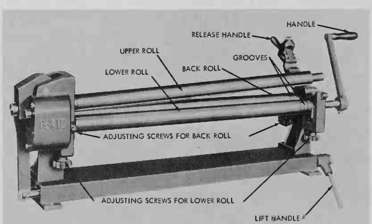


Fig. 5-25. Forming rolls. (Peck, Stow & Wilcox Co.)

form mild steel sheet metal as heavy as 22 ga. This machine has three rolls. The two front rolls grip the sheet of metal and force it against the rear roll, which bends it upward curving the sheet and forming the cylinder. The lower front roll can be adjusted for different thicknesses of metal. The back roll can be raised or lowered to form different diameter cylinders. The back roll can also be set at an angular, vertical position for forming tapered cylinders. To form a cylinder follow this procedure:

1. Adjust the lower front roller up or down so there is just enough clearance between the two front rolls for the sheet metal to slip in under slight pressure.
2. The back roll is then adjusted to a position which will form the cylinder. There is no set rule that may be applied for setting the rear roll. Some metals have more spring than others. Therefore, the adjustment of the rear roll can best be obtained by experimenting. The back roll must be parallel to the front rolls.
3. Insert the sheet metal from the front of the machine between the two front gripping rolls. Turn the hand crank and feed the metal through the front rolls and against upper side of the rear forming roll which bends the metal upward forming the cylinder, Fig. 5-26.

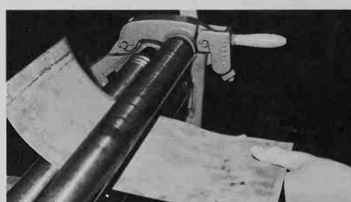


Fig. 5-26. Back roll beginning to form a cylinder.

4. Continue turning the hand crank to shape the cylinder. Readjust the back roll if the cylinder is not the correct radius. Lowering the rear forming roll will increase the diameter of the cylinder, and raising the rear forming roll will decrease the diameter of the cylinder.
5. Remove formed cylinder from rolls, Fig. 5-27.

To form cone-shaped pieces on the forming machine, adjust the front rolls as before. Set the rear roll at an angle that is approximately the same as the taper of the cone, with the left end of the roll nearer the front rolls. Insert the metal with the long side to the right. Hold the short side of the metal so it will go

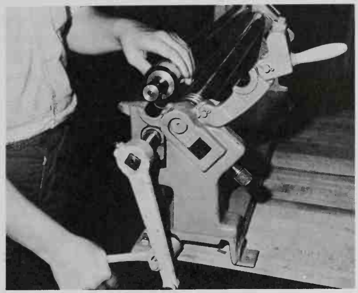


Fig. 5-27. Removing a cylinder from the forming rolls.

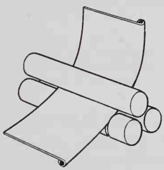


Fig. 5-28. Forming a piece of metal in the rolls with a wired edge.

through the rolls more slowly than the long side as the cone is formed.

The grooves of varying sizes in the right end of the lower and rear rolls are for forming cylinders which have a wired edge, Fig. 5-28. The procedure for forming wired edge metal is the same as described before, except when forming wired material heavier or lighter than 20 ga. When forming wired material heavier than 20 ga. the rear roll of the forming machine must be set at a distance that is slightly greater at the wired end than at the opposite end. Wired material lighter than 20 ga. requires an adjustment that provides a distance between the rear roll and both the upper and lower rolls that is greater at the wired end than at the opposite end.

SHEET METAL SEAMS

A great many methods are employed to strengthen and join pieces of sheet metal. Some of the common

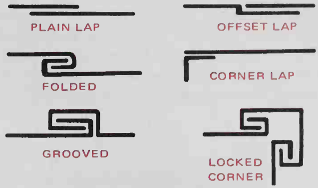


Fig. 5-29. Some of the common sheet metal seams.

seams are shown in Fig. 5-29. Lap seams are generally used in the construction of rectangular objects and small diameter cylinders. Lap seams are usually riveted or soldered. Folded seams are generally used when laying flat seam metal roofing. A folded seam is made by turning single edges on the two pieces of the sheet metal that are to be joined, Fig. 5-30. Allow

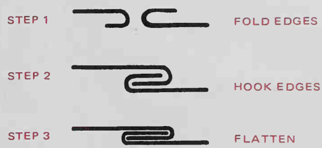


Fig. 5-30. Steps in making a folded seam.

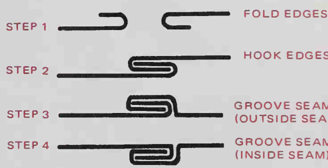


Fig. 5-31. Steps in making a grooved seam.

extra material equal to three times the seam width. Hook the two edges together and place the metal over a stake if the work is circular, or on a solid flat surface if the piece is flat. Hammer the seam flat with a wood mallet. Grooved seams are generally used in joining flat pieces of metal, making vertical side seams, in flaring or cylindrically shaped objects, and

making longitudinal seams in square or round sheet metal pipes, Fig. 5-31. To make a grooved seam, follow the procedure given for making a folded seam up to the steps given for closing the seam. To close the seam, select a hand groover of the required size,

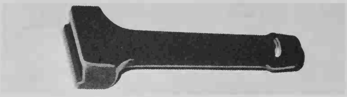


Fig. 5-32. A hand groover.

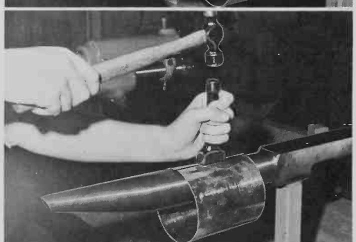


Fig. 5-33. Above. Locking the end of a seam. Fig. 5-34. Below. After both ends have been locked, complete the seaming operation by working back and forth across the seam, striking the groover moderate blows.

Fig. 5-32. Always use a hand groover approximately 1/16 in. wider than the finished seam. Place the piece on a suitable support. Set the groover exactly over one end of the seam. Strike the groover a firm blow to close the seam, Fig. 5-33. Continue working back and forth across the seam striking the groover moderate blows with a metal hammer to complete the seam. Fig. 5-34.

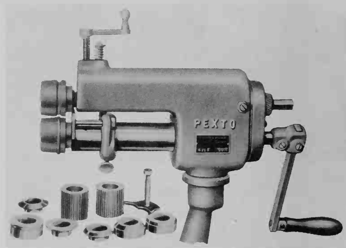


Fig. 5-35. A combination rotary machine with several sets of rolls.

USING A ROTARY MACHINE

A rotary machine consists mainly of a rigid cast iron frame fitted with shafts, gears, and several different sets of rolls, Fig. 5-35. This machine can be set up to perform beading, crimping, burring, wiring, and turning. To save time, some shops are equipped with a separate machine for each operation so the rolls do not have to be changed.

Wiring an edge on a rotary machine is accomplished by setting the machine up with various sets of rolls. Following is the procedure:

1. Determine the size of wire to be used.
2. Lay out stock, making allowance for the material needed to make the wired edge. The amount of extra stock needed for 22 ga. or lighter is equal to 2-1/2 times the diameter of the wire. For example, if the wire is 1/8 in. in diameter: 2-1/2 x 1/8 in. = 5/2 x 1/8 = 5/16 in.—the additional amount of stock required.
3. Cut stock to correct size. The edge to be wired must be perfectly straight.
4. Install the turning rolls on the rotary machine, Fig. 5-36.
5. Measuring from the center of the groove in the lower roller, set the gage a distance equal to two and one-half times the diameter of the wire.

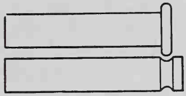


Fig. 5-36. A set of turning rolls.

6. Place the metal between the two rolls with the edge firmly against the gage, Fig. 5-37a.
7. Tighten the upper roll until it grips the metal. Turn the hand crank and feed the metal through the rolls until one complete turn has been made. Guide the metal carefully so the groove is even.
8. Lower the upper roll by tightening the crank screw about one-eighth of a turn. Tilt the work upward slightly as in Fig. 5-37b. Turn the crank until another complete revolution has been made.
9. Continue tightening the upper roll after each pass. Tilt the body of the work a little higher with each pass until a U-shaped groove is formed, Fig. 5-37c.

The next step is to install the wiring rolls, Fig. 5-38, on the machine and close the wired edge by following this procedure:

1. Select and cut a piece of wire of the correct diameter and length.
2. Adjust the gage a distance from the sharp edge of the upper roll equal to the diameter of the wire, plus twice the thickness of the metal.
3. Insert the wire in the seat formed with the turning rolls. Shape the wire so it will fit in the seat easily.
4. Place the article to be wired between the rolls, with the wired edge up, and against the gage, Fig. 5-38a. Lower the upper roll until the roll grips the work firmly.
5. Turn the crank until the edge being wired has traveled through the rolls.
6. Lower the upper roll a little farther and feed the work through again. Continue this procedure until the metal is folded firmly around the wire. On the last pass, tilt the work upward slightly to force the edge of the metal under the wire.
7. Loosen the upper roll and remove the work.

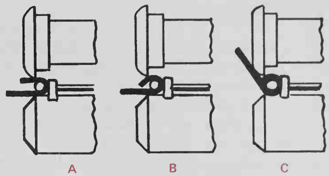


Fig. 5-38. Closing a wired edge.

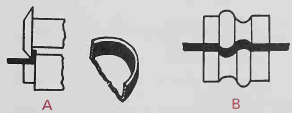


Fig. 5-39. (A) Turning a flange; (B) Beading.

Burring rolls which are generally furnished with a rotary machine, are used to turn a flange on a cylinder, and to turn a burr on a bottom in making a double seam to attach to a cylinder, Fig. 5-39a. The beading rolls are used to decorate and strengthen the sides of sheet metal projects, Fig. 5-39b.

FASTENING SHEET METAL

There are several methods used to join sheet metal pieces together. You will want to become familiar with some of the most common processes by using them when you construct your projects. Procedure are given in this unit for riveting, soldering and the use of sheet metal screws.

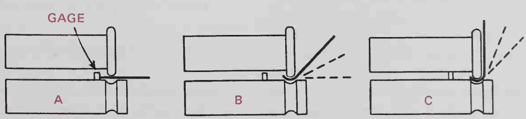


Fig. 5-37. Steps in using the turning rolls to form an edge to receive a wire.

RIVETING

Rivets are used to join two or more sheets of metal together permanently. The rivets used are generally made of aluminum, copper or iron. It is customary to use rivets of the same metal as the parts that are being joined. Round head and flat-head solid rivets are more commonly used. Tinner's rivets are used on thin black iron, galvanized iron, and tin plate. They have flat heads and are made of soft iron or steel. They are usually coated with tin as a protection against corrosion. The sizes are designated by the weight of 1,000 rivets. The length of a tinner's rivet is proportionate to its weight and diameter, Fig. 5-40. All rivets of one size are the same length.

Fig. 5-40. Tinner's rivets (actual size).

The following procedure is generally used when riveting sheet metal:

1. Select the rivets to be used. The size rivet depends on the thickness (gage) of metal being joined and the diameter of the rivet shank. In general the rivet shank should extend from one to two diameters beyond the material. The diameter of the rivet should not be less than the total thickness of the pieces being joined.
2. Lay out the location for the rivets on the work-piece. All of the holes must be properly spaced and lined up. The spacing of rivets is determined by the type of material used and the nature of the work. For most practical purposes, a good rule is--minimum distance between rivets should be three diameters of the rivet shank, and the maximum, eight diameters. The distance from the edge of the work should be two diameters of the rivet shank.
3. Drill or punch the holes. Holes in thin metal are usually punched. Place metal over the end grain of a hardwood block or a lead block. Set the punch over the place where the hole is to be punched. Strike the punch solidly with a hammer to form the hole, Fig. 5-41. To be sure the holes in the pieces being joined will line up, drill or punch all of the holes in one of the pieces, and only one hole in the second piece. Join the two

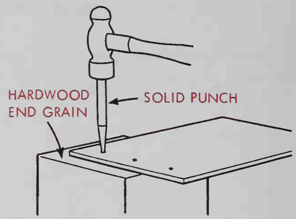


Fig. 5-41. Punching holes for rivets with a solid punch.

pieces with a rivet. Using the holes already drilled in the first piece as guides, drill the rest of the holes in the second piece.
4. Set the rivets. Place the rivet in the first hole with the head down on a flat, solid surface. If the work being riveted is cylindrical, place the rivet in the hole with the head of the rivet down on the crown of a stake. Place the hole of the rivet set over the rivet shank, Fig. 5-42a. Strike the

Fig. 5-42. (A) Setting a rivet; (B) Heading a rivet.

rivet set with a hammer to flatten the sheet metal around the hole and draw the sheets together. Keep the rivet set square with the surface of the sheet metal so it will not dent the work.
5. Head the rivet by striking the shank several direct blows with a hammer to expand the shank slightly beyond the hole. Form the head of the rivet by placing the cone-shaped depression of the rivet set in a vertical position over the shank. Then strike the rivet set with a hammer several times to round off the head, Fig. 5-42b. Be careful not to dent the sheet metal.

SHEET METAL SCREWS

Sheet metal screws are used in sheet metal work to join and install duct work for heating, ventilation, and air-conditioning. Many of our appliances are

covered with sheet metal cases which are joined with sheet metal screws. These screws are known in the trade as self-tapping screws since they cut their own threads in mild and soft sheet metal. They are available in both sharp and blunt ends, Fig. 5-43. The blunt-end screws are generally found to be most satisfactory, but the pointed type is used if alignment of holes is difficult. The sharp pointed screws are generally used to join material which is lighter than .050 in. thick. The blunt end screws are used for sheets from .015 to .203 in. thick.

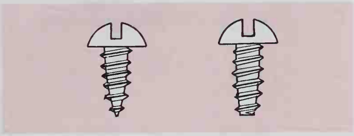


Fig. 5-43. Sheet metal screws. Left. Type A with sharp point. Right. Type Z with blunt point.

Screw Size	Metal Thickness	Drill Size No.
No. 4	.018	44
	.024	42
	.030	42
	.036	40
No. 6	.018	39
	.024	39
	.030	38
	.036	36
No. 8	.018	33
	.024	33
	.030	32
	.036	31
No. 10	.018	30
	.024	30
	.030	30
	.036	29

Screw Size	Metal Thickness	Drill Size No.
No. 4	.018	44
	.024	43
	.030	42
	.036	42
No. 6	.018	37
	.024	36
	.030	36
	.036	35
No. 8	.024	32
	.030	31
	.036	31
No. 10	.024	27
	.030	27
	.036	26

Fig. 5-44. Left. Recommended drill sizes for self-tapping, sharp pointed sheet metal screws. Right. Drill sizes for self-tapping blunt-end sheet metal screws.

Procedure for using sheet metal screws:

1. Lay out the holes and prick punch the locations.
2. Choose the correct size drill, Fig. 5-44. The drill size should be equal the root diameter of the screw. Drill the hole.
3. Line up the hole and start the screw. Be sure the two pieces of metal are held together firmly. Then fasten the screw with a screwdriver.

BLIND RIVETING

Blind rivets are made so all of the riveting is done from one side of the metal. The most commonly used blind rivets are made of steel and aluminum. To use the rivet tool, Fig. 5-45, start by drilling the proper size hole for the rivets to be used. Place a rivet in the tool. Hold the head of the rivet tight against the work. Squeeze the handles of the tool until the mandrel of the rivet breaks off.

Fig. 5-45. Riveting tool used to install blind rivets.

SOFT SOLDERING

Soldering is the process of fastening two or more pieces of metal together by means of an alloy (solder) having a lower melting point than that of the pieces being joined. Soft solders are made of varying percentages of tin and lead. The most common compositions are 40/60, 50/50 and 60/40 (first number is always tin). A good all-round solder contains 40 percent tin and 60 percent lead. It becomes completely liquid and mobile at 460 deg. F (238 C). Some craftworkers prefer 50/50 solder, also called "half and half," which becomes completely molten at 414 deg. F (212C). Solder is available in

bars, solid wire and acid or rosin-core wire, which has the flux in the center of the wire.

Fluxes remove oxide from the metal, and prevent new corrosion. Also, molten solder will flow more easily and penetrate where it should. There are two classes of fluxes, corrosive and noncorrosive. The corrosive works best but must never be used on electrical connections. Corrosive flux must be washed from the metal with warm water after soldering.

Soldering requires a source of heat. A common method used to transmit heat to the metal surface being joined is by means of a soldering copper, Fig. 5-46. The working end of this tool is made of copper

Fig. 5-46. A soldering copper.

because it is an excellent conductor of heat. Soldering coppers are available in several weights. A copper weighing 1/2 lb. is best for light work, a 1 lb. copper for medium work, and a 1 1/2 lb. copper for heavier jobs. A gas bench furnace can be used to heat the soldering copper, Fig. 5-47. An electric copper with interchangeable tips, Fig. 5-48, or a soldering gun, Fig. 5-49, is very convenient for light work and is especially good for soldering electrical connections.

Soldering coppers must be tinned before they will do a good job of soldering. After a soldering copper has been used for some time, or if it has been overheated the point becomes covered with oxide.

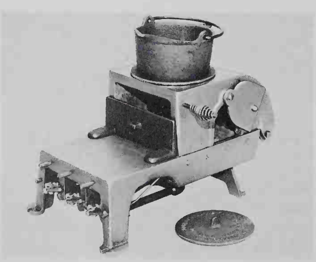


Fig. 5-47. A gas bench furnace. (Johnson Gas Appliance Co.)

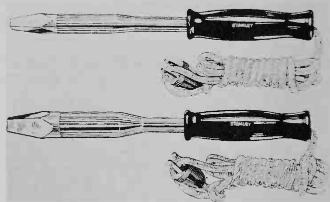


Fig. 5-48. Electric soldering iron.

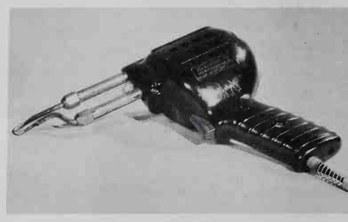


Fig. 5-49. A soldering gun.

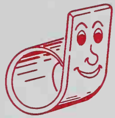
This oxide prevents the heat from flowing to the metal. To tin a soldering copper:

1. File the faces of the point with a mill file until they are smooth, flat and clean.
2. Heat the copper to melt the solder.
3. Rub the faces of the point on a sal-ammoniac block while the point is hot.
4. Apply solder to the point as it is rubbed on the sal-ammoniac. A thin, bright film called tin will form if the copper is not over-heated.
5. Remove excess with a rag.

Liquid flux can be used instead of the sal-ammoniac for tinning by dipping the point into the flux and rubbing it with solder.

The following procedure should be followed to insure a strong, neat soldering job:

1. Clean the surfaces to be soldered. Solder will not stick to dirty, oily, or an oxide coated surface. Liquid cleaner can be used to clean a dirty



CHIP SAYS:

"Avoid breathing fumes from the sal-ammoniac – they cause headaches and injure the lungs."

surface. Remove oxide from the metal with abrasive cloth.

2. Use a properly tinned copper.
3. Keep the surfaces to be joined close together to insure a strong bond, seam, or joint.
4. Flux only the area to be soldered. Be sure to use the proper flux for the job.
5. Heat the soldering copper to the proper temperature. Copper should be hot enough to melt solder readily. Do not allow it to become red-hot.
6. Tack the seam or joint by applying solder at several points. This is done by placing the point of the soldering copper on the metal where it is to be tacked. Hold it there until the flux sizzles. Then apply a small amount of solder to the metal directly in front of the point of the copper.
7. Place one face of the copper flat against the metal at one end. Hold it there until the solder melts, Fig. 5-50.

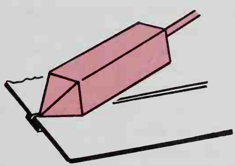


Fig. 5-50. Hold one face of the soldering copper flat against the surface of the metal.

8. Draw the copper SLOWLY along the seam or joint in one direction only, flowing the solder on in front of the point. The soldered joint or seam will not be satisfactory if the solder is just "stuck on" or melted on.
9. Do not move or handle the soldered job until the solder has "set" and has partially cooled. Solder is brittle and weak while solidifying.
10. If an acid flux has been used, wash off all traces of the flux with running warm water.

Sometimes it is necessary to solder several thicknesses of metal together or to apply one piece of metal to another so the solder will not show. This is called <u>sweat soldering.</u> In sweat soldering, the contacting surfaces of the metal is coated with a thin, even coating of solder. The surfaces are then placed together and heated with a large copper or a torch until the solder melts. This "sweats" the pieces of metal together. Use plenty of flux and be sure the pieces being joined are clean.

QUIZ – UNIT 5

1. List three major building trades that employ sheet metal workers.
2. In sheet metal work a development or pattern is called a ________.
3. List three kinds of pattern development.
4. When cutting sheet metal that is 22 ga. or lighter you can use straight snips for ________ cuts and to cut large ________ curves.
5. Hawk-bill snips are used for making ________ cuts.
6. A hatchet stake can be used to make ________ bends.
7. A cone-shaped piece of metal can be formed over a ________ stake.
8. List four sheet metal operations that can be performed on a bar folder.
9. What is the function of the back roll of a forming machine?
10. What is a hand groover?
11. Figure the amount of material needed to make a wired edge on a piece of 22 ga. metal, using 1/16 in. wire.
12. The diameter of a sheet metal rivet should not be less than the ________ ________ of the pieces being joined.
13. A ________ ________ is used to "head" a rivet.
14. Sheet metal screws are available in both ________ and ________ ends.
15. What size drill should be used for a No. 6, sharp pointed sheet metal screw, to join metal that is .030 in. thick?
16. List four forms of solders.
17. Why must the oxide which forms on the point of a soldering copper be removed?

Unit 6
FORGING

After studying this unit, you will know:

1. **How to form metal by forging.**
2. **Forging tools and equipment.**
3. **Hand forging procedures.**

One of the earliest methods of forming iron was by hand forging. In hand forging, the metal is heated in a forge and shaped over an anvil with hammers and tools of various kinds. Today, industry has speeded up forging for production by using various kinds of machine-powered hammers or presses that are used instead of hand sledges. These machines can forge such items as tools, axles, and crankshafts for an automobile engine. Some of the jobs in a forge shop require skill in the operation of power hammers. People who operate power hammers are called hammersmiths. The hammer which moves up and down under power shapes the heated metal. The hammersmith controls both the strokes of the hammer and the movement of the metal as it is shaped.

You will find hand forging a very interesting area of metalwork. There is something facinating about hammering red-hot steel which is soft and plastic. You will also find forging useful in making repairs on metal parts around the home and in the shop.

CAREER OPPORTUNITIES

The basic equipment used in this field of work includes hand tools (hammers, tongs, and anvil with hardies), various types of power hammers, power forming and trimming presses, dies, and furnaces. A forging press or hammer generally is operated by a crew of two to ten workers. The size of the crew depends on the work piece size and the operation to be performed.

Major forging occupations are as follows: Hammersmiths — interpret blueprints, determine the force of the hammer for the job, and decide the correct amount of heating needed for the work piece. They must also know how to use the various forming tools. The hammersmith supervises the crew. Hammer Operators — operate huge presses equipped with either open or impression dies. This work differs from that of the hammersmith mainly because this operation shapes and forms hot metal by pressing or squeezing rather than by hammering. They must know how to regulate their machines, the proper heat of metal being formed, and how to set up dies in the press. Upsetters — shape hot metal by applying pressure through the horizontal movement of one impression die against another. The duties require the aligning of dies, positioning metal stock between the dies, adjusting the required pressure, and proper heating of the metal stock. Heaters — must know how to adjust the furnace to obtain the temperature and atmosphere required. They read temperature gages and observe the color of the metal to determine when the correct temperature of the metal has been reached. They use tongs or mechanical equipment to transfer heated metal from the furnace to the hammer or press. Inspectors — check forgings for specifications as they relate to size, shape, and quality. This inspection may be done visually or with measuring instruments depending upon required accuracy. They also check forgings for strength and hardness with machines and testing devices. Diesinkers — are highly skilled persons. They make the impression dies. Working from a blueprint or drawing, diesinkers form the shape of the die blocks with machine tools. EDM (electric discharge machining) and ECM (electrochemical machining) are new processes being used by sinkers to machine the dies today. In addition, sinkers must be skillful in the use of hand tools, such as grinders and scrapers which are used to smooth and finish the die cavity.

Other forge shop workers clean and finish the forgings. These jobs include trimmers, grinders, sandblasting or shotblasting, picklers, and heat treaters.

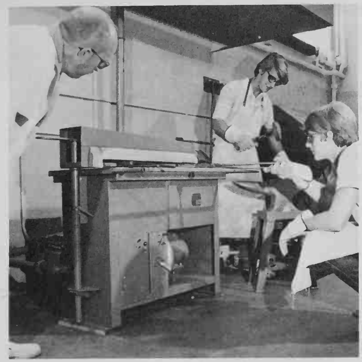


Fig. 6-1. A gas fired forge. (Johnson Gas Appliance Co.)

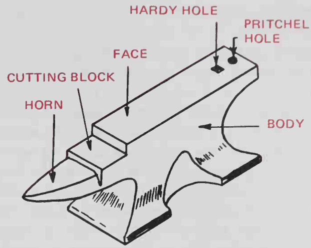


Fig. 6-2. The parts of an anvil.

THE FORGE

A forge is used to heat the metal to be shaped. It may be a gas or oil-fired furnace, or a coal forge, Fig. 6-1. To light a gas or oil furnace, place a lighted piece of paper in the fire box close to a burner. Turn on a small amount of air and then a little fuel until the furnace lights up. As the furnace heats up, turn on more fuel and air until the flame is blue. Too much air causes the formation of a heavy scale on the metal being forged. When you are through using a forge, close the gas and air valves.

ANVIL

Metal is hammered and bent into shape on an anvil, Fig. 6-2. The size of an anvil is determined by its weight. Commonly used sizes weigh from 150 lbs. to 300 lbs. A 100 to 200 lb. anvil is suitable for school use. Most anvils have either a cast steel, or cast iron body. The face is made of hardened steel welded to the body. It is smooth and should be kept free of dents and marks. The horn which is shaped like a cone is unhardened but tough. It is used for shaping rings, hooks, and curved parts. The cutting block which is located between the face and the horn, has a soft surface. It is used when cutting or chipping metal with a cold chisel--do not use the face for these operations. The hardy hole is square. It is used to hold square shank tools such as hardies, swages, and fullers, Fig. 6-3. The pritchel hole is used for bending small rods and punching holes in metal.

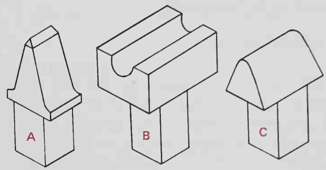


Fig. 6-3. Anvil tools. (A) Hardy to cut hot and cold metal; (B) Swage to smooth round stock (they are made in pairs--the one that goes on top has a handle); (C) Fuller, to form depressions in heated metal (they are also made in pairs).

HAMMERS

Hammers and sledges of different types are used in hand forging, Fig. 6-4. The size of a hammer is given in ounces or pounds. The most common sizes found in school shops are: the ball peen, 6 oz. to 2 1/2 lbs., and the cross and straight peen blacksmith's hand hammers, 1 1/2 to 3 1/2 lbs. These hammers are usually made of forged steel, hardened, and given a polished finish.

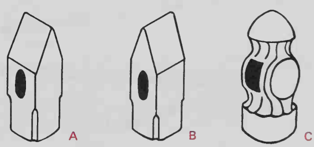


Fig. 6-4. Forging hammers. A—Cross peen; B—Straight peen; C—Ball peen.

FORGING PROCESSES

The metal must be heated to the correct temperature for shaping. Most mild steel should be heated to a good bright red. Thinner pieces of metal require less heat than thicker ones. Tool steel should be heated to a point between cherry red and orange. Never allow the metal to become so hot that sparks fly from it, since this causes the metal to oxidize and burn. Never hammer on tool steel after it loses the orange color and starts turning black since this will cause the metal to crack. All forging must be done at forging temperature, also with as few heatings as possible, because too much heating spoils the steel. Study each forging operation before starting, and have all the tools handy so when the metal is hot, hammering and forging can be done quickly.

HOLDING WORK

The metal to be forged must be held securely while it is being worked. A pair of tongs of suitable size and shape is used for this purpose. There are several sizes and shapes, but the most common are illustrated in Fig. 6-5. The straight-lip tongs that have a "V" notch in each jaw are used to hold square and round shapes, Fig. 6-5a. The other pair of straight-lip tongs is used to hold thin flat work, Fig. 6-5b. Single pick up tongs are designed for picking up either flat or round stock, Fig. 6-5c. The curved-lip tongs, with fluted jaws are used to hold bolts and irregular-shaped pieces, Fig. 6-5d. The jaws of the tongs must close evenly on the stock throughout their length, Fig. 6-6.

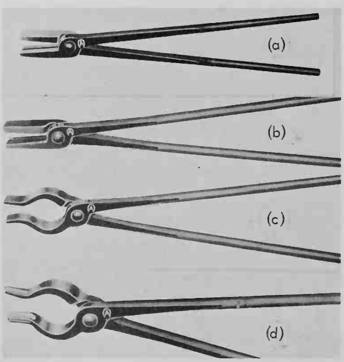


Fig. 6-5. Forging tongs: (A) Straight lip, with "V" notch in each jaw; (B) Straight lip; (C) Single pick up; (D) Curved lip, with fluted jaws. (Stanley Tools)

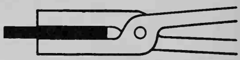


Fig. 6-6. Tongs gripping piece properly.

If tongs of suitable size are not available, slight adjustments can be made by heating and bending the jaws so that they close evenly on the stock.

UPSETTING METAL

The purpose of upsetting is to increase the thickness of the stock at a given point. This operation shortens the length of the piece so be sure to allow enough extra stock. To perform the upsetting operation, place the stock in the fire in a position that will heat the portion to be upset to a yellow heat. If the metal is long enough, pick it up with one hand and place the heated end on the face of the anvil, Fig. 6-7.

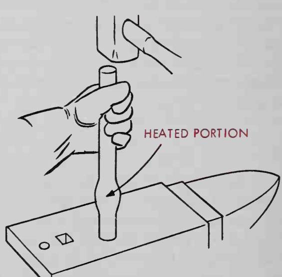


Fig. 6-7. Upsetting a piece of metal.

Working rapidly, strike the cold end of the stock hard blows with a heavy hammer. If the stock bends, lay it flat on the anvil and straighten it with the hammer. Then continue the upsetting process until the desired thickness is obtained. If the stock becomes hard to work because of cooling, reheat it and continue the process. When the stock upsets too quickly at the end, dip it in water and proceed in the usual manner.

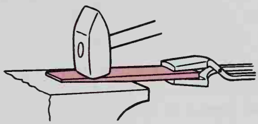


Fig. 6-8. Drawing out metal.

DRAWING OUT

In forging, drawing out stock means to lengthen the piece and to reduce a portion of it in size. The tapered part of a flat cold chisel is an example of drawing out metal. When forging mild steel, heat the portion to be worked to a bright yellow heat. Then quickly place the part to be drawn on the face of the anvil. Hold the piece firmly with tongs and strike the metal a few heavy blows, Fig. 6-8. Hold the hammer so that its face is parallel with the surface of the work piece when the blow is struck. Continue the drawing out process, rotating and striking the metal first on the broad face and then on the edge until the desired shape is obtained. While drawing out the metal each broad face should be hammered alternately. When drawing out metal to a round point as on a center punch, follow the steps shown in Fig. 6-9.

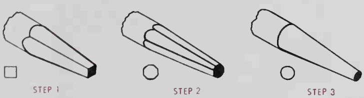


Fig. 6-9. Steps in forging the point of a center punch.

BENDING

To make a sharp bend, heat the stock at the point where the bend is to be made. Place the stock on the anvil face with the portion to be bent down at the edge of the anvil. Strike the extended portion moderate blows with the hammer to bend the stock down to the desired angle, Fig. 6-10. Angular bends can also be made in the hardy hole or pritchel hole of the anvil. Bars can often be bent in a vise. Thin metal can be bent cold; heavy pieces must be heated.

CHIP SAYS:

"Do not look into the opening of the furnace as the fuel is turned on. Do not operate the forge until your teacher shows you how.

Wear a face shield when hammering hot metal. The scale that flies is hot. Wear gloves when necessary and use tongs when handling hot metal. Wear an asbestos glove on the hand holding the stock. If the piece of metal is too short to hold by hand safely, grip it with tongs."

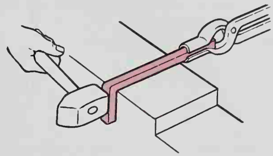


Fig. 6-10. Forging a sharp bend on the anvil.

FORMING AN EYE

Measure the length of metal it will take to make the eye, and mark the point with a prick punch. Heat the metal at this point, and bend it over the edge of the anvil to a 90 deg. angle, Fig. 6-11a. Heat and start bending the end to form the eye, Fig. 6-11b. Continue by heating and forming the eye over the anvil horn, Fig. 6-11c. Close the eye by holding it over the edge of the anvil, and striking it with a hammer, Fig. 6-11d.

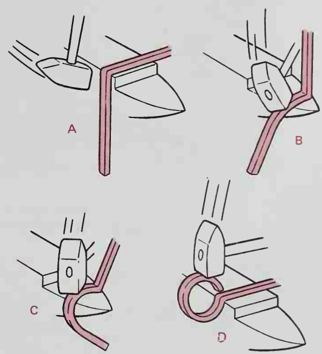
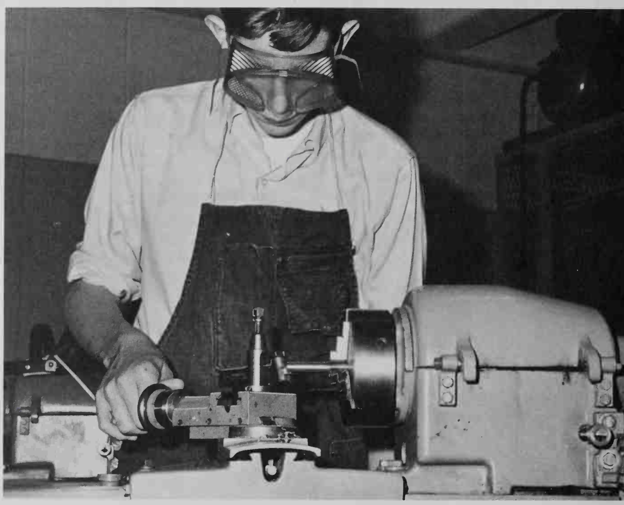


Fig. 6-11. Steps in forging an eye.

QUIZ – UNIT 6

1. What is forging?
2. What is the difference between production forging and the work of a blacksmith?
3. List the steps in lighting a gas forge.
4. What safety precautions should be followed when lighting the forge?
5. What are the parts of an anvil?
6. What is the proper heat for forging tool steel (as determined by color of metal)?
7. What is meant by drawing out metal?
8. What is the procedure for upsetting metal?
9. What are the steps for forming an eye?
10. List two safety precautions to be followed when doing hand forging.



In the school shop where there is danger of injury from flying metal chips, the importance of proper eye protection cannot be overemphasized.

Unit 7
WELDING

After studying this unit, you will know:
1. **Career opportunities in the field of welding.**
2. **Welding with oxyacetylene equipment.**
3. **Types and preparation of welded joints.**
4. **Brazing metal.**
5. **Arc welding and spot welding.**

Welding is the process of joining metal pieces by heating them to the melting point, and allowing the molten portions to fuse or flow together. This process may be done with or without pressure. Industry uses welding to join parts together because it is an efficient, dependable, and practical process. The oldest form of welding is forge welding, which has been practiced by blacksmiths and other artisans for centuries. Today, industry is using many modern welding techniques that make it possible to join most any metal or alloy. Welding can be applied to practically all types of metal from large castings and huge structural shapes to the thinnest of sheet metals. In this unit we will study oxyacetylene, simple arc and spot welding processes.

CAREER OPPORTUNITIES

There are many jobs in the field of welding. With new welding techniques and wider use of welding processes, the number of jobs in this field will most probably increase. The principal employers are automobile manufacturers, aircraft plants, sheet metal fabricators, shipyards, steel mills, construction industries and repair shops. The earnings of highly skilled manual welders compare favorably with those of other skilled metalworking jobs. Flame-cutting and resistance welders who require little training, earn less than the skilled manual welders. Welding requires a steady hand, manual dexterity, and good eyesight. In addition to the development of skill in using welding equipment, the craftworker in this field of work must have a knowledge of blueprint reading, properties of metal, and planning procedures. A growing career in the welding field is the position of a welding technician. This job involves interpreting the engineers' plans, specifications, and being able to follow their instructions. As new and more sophisticated welding processes are developed, technicians will be in great demand.

OXYACETYLENE WELDING

The oxyacetylene welding process, usually called "gas welding," is done with a torch. The torch mixes oxygen and acetylene gases to provide fuel for the flame. This flame can be controlled to produce the heat required (6000 deg. F or 3315 C) to melt and fuse the metals being joined.

EQUIPMENT

Welding equipment, Fig. 7-1, includes two cylinders, one oxygen and one acetylene. These cylinders are equipped with regulators that can be adjusted to

Fig. 7-1. Oxygen and acetylene cylinders should be mounted vertically in a truck or chained to a post.

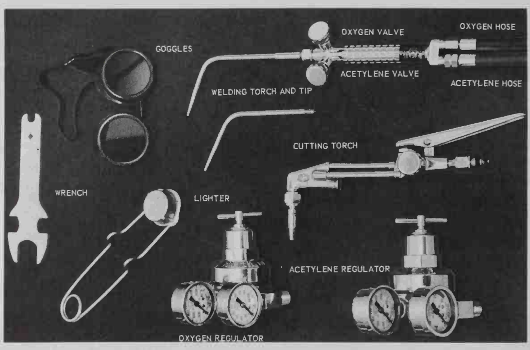


Fig. 7-2. Basic accessories for welding with oxyacetylene.

reduce the high cylinder pressures. Most regulators are equipped with two gages. One gage indicates the cylinder pressure and the other gage the amount of pressure in the hose. Two lengths of hose provide a means for carrying the gas from the cylinders to the welding torch which can be fitted with different size tips. To assist in identifying these hoses, they are color coded. The oxygen hose is green and the acetylene hose is red. Some of the basic accessories required for welding with oxyacetylene are shown in Fig. 7-2. In addition to those shown, fireproof gloves and a fireproof apron are needed.

TYPES AND PREPARATION OF JOINTS

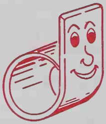
Before welding you must decide which type of joint should be used for the job. The type of joint depends upon the kind of material, its thickness, and the nature of the job. To obtain a sound weld, the joint must be clean. Rust, scale, oil, and other impurities must be removed from the base metal.

Five basic types of joints that are common to both oxyacetylene and arc welding are: The butt joint, Fig. 7-3, Tee joint, Fig. 7-4, Lap joint, Fig. 7-5, Edge joint, Fig. 7-6, and Corner joint, Fig. 7-7.

The American Welding Society has established a set of standard welding symbols for these joints. These symbols are used by the drafter to tell the welder what kind of weld should be made. Symbols indicate the exact specifications for welding operations to be done on the work piece. Before welding according to a blueprint or a drawing that has welding symbols on it, you should study the American Welding Society's Standard Welding Symbols publication.

ADJUSTING EQUIPMENT FOR WELDING

Check with your instructor before attempting to adjust the welding equipment. Adjusting the equipment for welding must be done properly to prevent damage to the gages and to observe safety precautions. Following is the recommended procedure:



CHIP SAYS:

"Never play or get careless when using the welding equipment. Combustible gas and a fire must be handled carefully."

"Always wear welding goggles, fire-proof gloves, and fire-proof apron when using welding equipment."

"Always use the spark lighter to light the torch — never use a match."

"Turn off the torch if it becomes necessary to change the position of work pieces or when you have completed the weld. Always hang the torch up carefully."

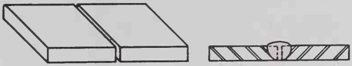


Fig. 7-3. Butt joint. Metal 1/8 in. thick can be welded from one side. Up to 3/8 in., weld joint on both sides. The joint must be beveled on thicker metal plate before welding.

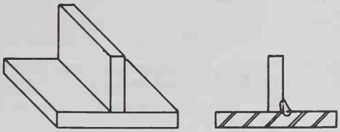


Fig. 7-4. Tee joint. Weld is made from one or both sides.

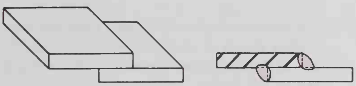


Fig. 7-5. Lap joint. Pieces to be welded should fit together tightly. A double weld is used when greater strength is needed.

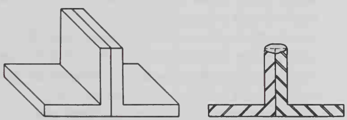


Fig. 7-6. Edge joint. This type joint is used where a great amount of strength is not needed. Generally the base metal serves as the filler metal.

1. Select the proper size tip for the job and carefully insert it in the torch. Refer to the chart furnished with the welding equipment for proper tip size. Be careful when tightening the tip to the torch so you do not strip the threads. Be sure the tip seats properly in the torch. If the tip needs cleaning, ask your instructor to give you the proper size tip cleaner.
2. Check the valves on the torch to be sure they are turned off (clockwise). Never close the valves too tightly, just tight enough to prevent gas from leaking through.
3. Back-off the adjusting screws on both gages until they are loose. This prevents a sudden surge of excessive pressure on the gages. Do not remove the screws from the gages.
4. Using the cylinder wrench, open the acetylene cylinder valve 1/4 to 1/2 turn.
5. Open the oxygen cylinder valve slowly, continuing to turn the valve until it seats against the top of the valve.

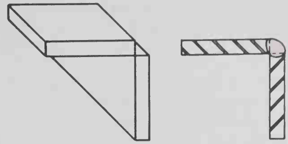
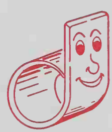


Fig. 7-7. Corner joint. Open corner joints are used when welding heavier plate. A light bead may be added to the inside to give the weld more strength.

LIGHTING THE TORCH

1. Open the acetylene valve on the torch and turn the acetylene regulator screw clockwise until the gage registers between five to eight pounds of pressure. Close torch valve.
2. Open the oxygen valve on the torch and repeat step number 1 for the oxygen. You will adjust the pressure differently for various size tips and welding jobs to be performed. Check the tip size and gas pressure chart prepared for the kind of welding equipment you are using.
3. The torch is ready to light. Put on the proper welding goggles and gloves.
4. Open the acetylene valve on the torch approximately 1/4 turn. Hold the torch with tip pointed away from the cylinders and your body. Light the torch with a flint lighter. NEVER USE A MATCH.
5. Quickly adjust the acetylene valve on the torch until the flame slightly extends from the end of



CHIP SAYS:

"When opening cylinder valves stand to one side of the regulator gages."

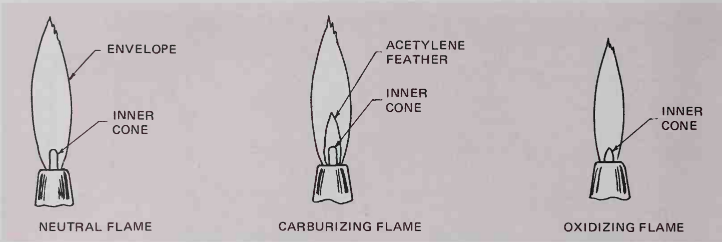


Fig. 7-8. Left. Neutral flame. The inner cone is smooth and rounded. Fig. 7-9. Center. A carburizing flame has three distinct flame sections. The inner cone is inside of another cone called acetylene feather. Fig. 7-10. Right. Oxidizing flame. The inner cone is sharp and pointed. The envelope is shorter.

the tip. Open the oxygen valve on the torch and adjust it to obtain the desired flame, Fig. 7-8. A neutral flame is best for most work. A carburizing flame, Fig. 7-9, is obtained when an excess of acetylene, which is indicated by streamers of acetylene (usually called feathers) comes from the inner cone. This kind of flame should not be used in fusion welding since it produces a brittle weld. An oxidizing flame, Fig. 7-10, is indicated by a hissing sound which is the result of too much oxygen. This kind of flame tends to burn the metal.

SHUTTING OFF THE EQUIPMENT

1. Close the torch acetylene valve first, then close the torch oxygen valve.
2. Close the acetylene cylinder valve first, then close the oxygen cylinder valve.
3. Open the torch acetylene valve to drain the gas from the regulator and hose.
4. Open the torch oxygen valve to drain the regulator and hose.
5. Turn out regulator screws on each regulator until they are loose to remove pressure from the diaphragms of the regulators.
6. Hang up the hose and torch. Do not put the torch or the hose over the cylinder regulators.

MAKING A PRACTICE WELD

Learning to weld takes considerable practice and experimentation. The quality of a finished weld is largely dependent upon the adjustment and manipulation of the flame. To see what effect the various flame adjustments have on a weld, make several practice runs on a piece of mild steel 3/16 in. thick by approximately 2 in. wide by 6 in. long.

1. Use a number 2 tip for this metal thickness. Place welding goggles on your forehead.
2. Put on welding gloves. Light the torch and adjust to a neutral flame.
3. Place the goggles over your eyes. Hold the inner cone of the flame about 1/8 in. above the piece of mild steel.
4. Hold the flame in one spot until a puddle 1/4 in. wide is formed. Keeping the puddle the same width, continue across the length of the practice piece of metal. Examine the results.
5. Adjust the torch to a carburizing flame. Run a bead parallel to the first bead about 1/2 in. over from it. Note the cloudy appearance of the molten puddle. Examine the results.
6. Adjust the torch to an oxidizing flame and run a bead parallel to the second bead about 1/2 in. over from it. Notice the violent agitation of the molten puddle. Examine the weld.
7. After the work piece has cooled, place it in a machinist's vise and bend it in the middle with a hammer. Examine the three welds. Note that the carburized bead may be cracked and the bead made with an oxidizing flame may have lost much of the scaled, oxidized material.
8. Take the work piece out of the vise and continue bending the metal until it is folded flat upon itself. The carburized and oxidized beads will probably be cracked while the bead made with a neutral flame bent as much as the original material without failure.

METAL THICKNESS	ROD SIZE (DIA)
18 gage	1/16 in.
1/16 in.	1/16 in. to 3/16 in.
1/8 in.	3/32 in. to 1/8 in.
3/16 in.	1/8 in. to 5/32 in.
1/4 in.	5/32 in. to 3/16 in.
3/8 in. and up	3/16 in. to 1/4 in.

Fig. 7-11. Recommended welding rod sizes for oxyacetylene welding. Mild steel welding rods are usually copper coated to prevent rusting. Cast-iron rods are square shaped. Brazing rods are made of brass or bonze. Mild steel and brazing rods are usually 36 in. long.

WELDING WITH FILLER ROD

After you have made the practice welds you should have a "feel" of the torch and control of the flame's distance from the work piece.

1. Prepare pieces of metal to be welded and arrange them in proper position on the welding table. Always wear proper goggles and gloves.
2. Select the proper size tip for the job and attach it to the torch.
3. Select the recommended rod size for the job. Check Fig. 7-11.
4. Set up the welding equipment and light the torch.
5. Adjust the torch for a neutral flame. Place the flame close to the joint. Move the torch in a small arc motion until the metal puddles (melts) and tacks together.
6. Using the same torch motion, start welding at the other end of the joint. Note: Steps 5 and 6 are very important. This keeps the joint of the two pieces being welded from spreading apart.
7. Add the filler rod to the joint as you weld. The rod should be moved in an arc opposite to the torch motion. Do not touch the torch tip with the rod. Keep the rod in the puddle. If the torch tip gets too close to the metal it will form small blow-holes in the weld and the torch may pop or backfire.
8. Develop a rhythm of torch and rod movement as you weld the joint. Also be careful to get good penetration as you fuse the rod and metal being welded.

BRAZING

Brazing is quite similar to soldering. An oxyacetylene welding torch is used to heat the metal until the brazing rod flows at the area being joined. The base metals are not melted. Joints that are properly brazed are very strong. A brazing rod, usually a copper alloy, and a matching flux are used. Rods and fluxes may be purchased for work at various temperatures and different types of metals.

1. Parts to be brazed must be clean and free of impurities. Joints should make a good fit.
2. Adjust torch to a neutral flame and apply heat to the metals being joined until they are red hot. Heat the end of the brazing rod slightly and dip in the flux, causing it to cling to the rod.
3. Holding the rod just ahead of the flame, continue to heat the metal pieces until the brazing rod melts and flows on the pieces being brazed. If the brazing alloy balls up and solidifies, the joint is not hot enough.
4. After proper temperature has been reached, continue brazing across the joint. Keep your torch in motion to prevent hot spots. Avoid overheating which often causes a weak joint. A properly brazed joint will have a bright shiny color after the flux has been washed off with water.

ARC WELDING

Arc welding is the process of fusing metals using the heat of an electric arc. The high temperature of this arc (electric spark) melts the metal, forming a molten puddle. An electrode used to create the arc melts and serves as the filler rod for the joint. Arc welders are rated according to their current output in amperes. Fig. 7-12 shows the kind usually found in the average school shop.

Fig. 7-12. AC welding machine. (Hobart Brothers Co.)

WELDING

1. Prepare and position the joint. Clamps may be needed to hold the pieces in place.
2. Place the proper electrode (check with your instructor) in the holder and clamp the ground cable to the workpiece or to the metal work table on which the workpiece is placed.
3. Adjust welder for correct amperage. Ask your instructor for best setting.
4. Wear arc welding gloves, apron and long sleeves as protections against burns from intense light and heat.
5. Wear a head shield, Fig. 7-13.

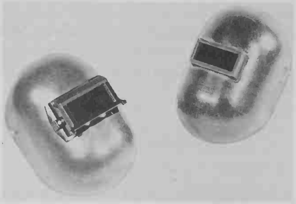
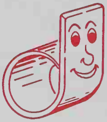


Fig. 7-13. Head shield for arc welding. (Hobart Brothers Co.)

6. Turn the machine on and bring the electrode within a few inches of the work piece.
7. Drop the shield over your eyes and strike an arc. This is accomplished by striking the work piece with the electrode like you strike a match. Then raise the electrode slightly to form and maintain the arc. Keep the electrode moving while starting the arc to prevent it from sticking to the work piece.
8. After you have obtained the arc, keep the electrode within 1/16 to 1/8 in. of the metal being welded. As the electrode burns shorter, keep feeding it to the work piece to maintain the correct arc length.
9. The electrode is moved in a straight direction without a circular or weaving motion. When the job requires a wide joint, a weaving motion is used. In some cases it is necessary to run additional beads. Be sure you get almost 100 percent penetration in the weld. In all cases get the deepest penetration possible.
10. The correct welding speed is most important. Move the electrode along smoothly and evenly. You can determine the correct speed by examining the weld. Moving too slowly will produce too much excessive build-up of the weld. Moving too fast produces a shallow, uneven bead.
11. Clean the weld bead with a chipping hammer. Wear your safety goggles when chipping and wire brushing the weld. Handle the hot metal with a pair of tongs.



CHIP SAYS:

"Never look at the arc with the naked eye. The arc can burn your eyes severely."

SPOT WELDING

This type of welding is a pressure-welding process called resistance welding. The weld is produced by heat generated by resistance to the flow of an electric current and by the application of pressure. Spot welding is used primarily in the fabrication of sheet metal. A filler metal is not needed. The weld is made between the metal pieces being joined.

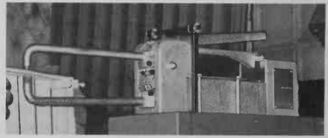


Fig. 7-14. Portable spot welder unit. (Miller Electric Mfg. Co.)

The spot welder, Fig. 7-14, is a portable hand operated machine. The machine has controls for regulating pressure, heat, and time cycle. The tips of the copper electrodes should be kept clean and properly shaped.

Spot welding is easy. If the proper procedure is used, the weld will be stronger than a rivet of equal diameter.

1. Clean the pieces of metal to be welded.
2. Turn on the electric power switch.
3. Clamp or hold the metal pieces together in the proper position and place the metal between the copper electrodes.
4. Apply pressure to the trigger or foot lever to make the weld. The pressure must be adjusted for different thicknesses of metal.
5. The correct weld time is very important. Spot welding machines are either controlled manually with the electric switch or they may have a built in timer which can be set.

QUIZ – UNIT 7

1. Welding is a process of joining metal pieces by ________.
2. Pieces of metal to be joined are heated at the point being welded to a temperature that ________ and ________ them together.
3. Name three principal employers of welders.
4. A growing career in the welding field is the position of welding ________.
5. The torch mixes ________ and ________ gases to provide fuel for the flame.
6. The flame burns at a temperature of over ________ deg. F.
7. The regulators used in oxyacetylene welding indicate ________ pressure and the amount of pressure in the ________.
8. Name the five basic types of joints common to both oxyacetylene and arc welding.
9. Who establishes the standard welding symbols that tell what kind of joint should be made?
10. What type of flame is best for most welding jobs?
11. If the torch tip gets too close to the metal being welded it will cause small ________ to form in the metal.
12. What size filler rod would you use when welding 18 gage metal?
13. When brazing, the base metals are not ________.
14. What is wrong if the brazing alloy balls up and solidifies on the pieces of metal being brazed?
15. Arc welding is a process of fusing metals with an ________.
16. Why shouldn't you look at the welding arc with the naked eye?
17. After the arc has been obtained, keep the electrode within ________ in. to ________ in. of the metal being welded.
18. Spot welding is a ________ welding process.
19. Spot welding is used mostly in the fabrication of ________.
20. When spot welding, the correct weld ________ is very important.

The new technological developments in the welding field, like this plasma arc welding, are increasing the demand for highly skilled technicians in the welding trades. (Hobart Brothers Co.)

Unit 8
HEAT TREATMENT OF STEELS

After studying this unit, you will know:
1. **How to anneal, harden, and temper steel.**
2. **How to determine different temperatures by colors of heated metal.**
3. **How to caseharden low-carbon steel.**

Heat treating is a process of heating and cooling steel in certain ways to change its properties. By properly heat treating, metals can be made harder and tougher. After you have made a cold chisel, center punch, screwdriver blade or any small tool, it will be necessary to heat treat it to make it useful. If the tip of a screwdriver blade, for example, is too hard it will be brittle and chip off when used. If the tip is too soft it will bend, so to be useful the tip of the blade must be heat treated. Tools must have a certain hardness, toughness, and brittleness to do their work. To obtain these characteristics there are four principal operations which may be performed to properly heat treat a piece of steel for its particular use. These operations are: Hardening, Tempering, Annealing and Casehardening.

HARDENING

Hardening is a process of heating steel to a certain temperature and then quenching (cooling) it in a suitable medium such as water, oil, or brine, depending upon the type of steel being hardened. Hardening is done in a furnace heated with oil, gas, electricity, or solid fuel. The steel is first heated to the desired temperature above the critical range in order to get the correct grain structure, and is then cooled quickly in a quenching medium in order to preserve this structure. Steel companies can supply information concerning temperatures and quenching procedures for their steels. This information is also given in Machinist's Handbooks. The temperature can be checked with a pyrometer attached to the furnace, a magnet, or by observing the color. A pyrometer, which is an electric thermometer, accurately registers the temperature in the furnace. Steel is magnetic until it reaches the critical temperature, then it is non-magnetic. When using this method, heat the metal until the magnet stops picking it up. The metal should then be suddenly cooled. Determining the temperature by observing the color of the hot metal is not too accurate. However, the old time heat treater used this method for many years.

The hardness depends upon the amount of carbon in the steel, the temperature of the heated steel, and the speed of cooling.

TEMPERING

Tempering is a process which is used to remove a certain degree of hardness and brittleness of steel and increase its toughness. Tempering is also referred to as drawing the temper. Hardened steel breaks easily and is too hard and too brittle for many tools. Therefore, it is necessary to remove some of the hardness by softening the metal. Steel can be tempered using the color method as a guide to the proper temperature. The temper is gaged by the colors formed on the surface as the heat increases, Fig. 8-1. A modern method which is used when a quantity of pieces are to be tempered, is to place the hardened metal in a bath of molten lead, heated oil, or other liquids and heat them to the required temperature. The metal is

Degrees Fahrenheit	Colors For Tempering
440	Yellow
460	Straw-yellow
470	Straw
500	Brown
520	Brown-purple
540	Purple
570	Blue

Fig. 8-1. Colors for tempering.

then removed from the bath and quenched. The bath method does a more uniform job of tempering, and the temperature can be held to close limits.

ANNEALING

Annealing is the opposite of hardening. It is a process of softening steel to make it easier to machine, cut, stamp, or shape, and to relieve stresses and hardness resulting from cold working. In annealing, the metal is cooled as slowly as possible. The slower the cooling, the softer it is when cold. To anneal steel, heat it slowly to the critical temperature. Cool it slowly by packing it in hot ashes to keep the air away, or it may be cooled off with the furnace.

CASEHARDENING

Casehardening is the hardening of the outer surface of metal. Only low-carbon steel and wrought iron can be casehardened. This process adds a small amount of carbon to the case (outside) of the metal part so it can be heat treated and made hard. The center, or core of the metal remains soft. Casehardening is done to parts which need a hard wearing surface such as gears, screws, hand tools, and roller bearings. Industry uses several methods to caseharden parts. Cyaniding is a common one and is done by placing the metal in a bath of molten cyanide. This method is too dangerous however for school shops. Carburizing is another method. This work is placed in a metal box containing a mixture of bone, leather, charcoal and carburizing materials. Then, the container is sealed and heated to 1650 deg. F (899 C) so the piece soaks up the carbon and forms a high carbon case on the outside. The piece is cooled in the carburizing box. Take the piece out of the container, reheat it to the critical temperature and quench.

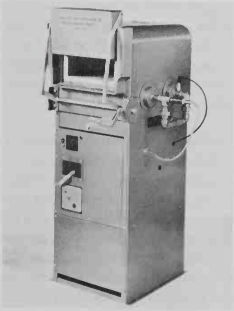


Fig. 8-2. This gas fired heat treating furnace will reach 2300 deg. F (1260 C). (Johnson Gas Appliance Co.)

HEAT TREATING PROCEDURE

Many of the projects made in the school shop require heat treatment. Cold chisels, center punches, hammer heads, and small parts can be heat treated very successfully with inexpensive equipment. The source of heat can be a small gas or oil-fired furnace, Fig. 8-2, blowtorch, forge, gas welding torch, or a bench soldering furnace. The quenching bath can be a pail of water, tempering oil, or brine, depending on the type of metal. Forging tongs can be used to hold the hot metal.

The tool steel used in most school shops is a water-hardening type. It is generally in an annealed state ready for cutting, drilling, filing, or machining. If it becomes necessary to heat the metal for certain operations, you will have to anneal it again if more cutting or shaping has to be performed. Annealing, hardening, and tempering operations may occur as a series of steps in the heat treatment operations, or annealing may be a separate process to remove internal strain developed while the metal is worked. Hardening may be done without performing either of the other processes. Tempering always follows annealing and hardening. Following is the procedure you may use to heat treat shop projects:

ANNEALING

1. After the piece has been forged to shape, heat it throughout the portion to be annealed. A moderate flame should be used if gas is the source of heat.
2. Turn the metal as it is heated until it reaches a cherry red or the color just below the critical range of the steel being annealed.
3. Remove the metal from the heat and cover it immediately with pulverized coke or air slaked lime. Keep the metal covered until it is cold.

HARDENING

1. Heat metal to critical temperature. For example, .70 to .90 carbon, water-hardening, tool steel is heated to 1450-1550 deg. F (788-843 C). The

Deg. F	C	Color
752	400	Red heat (visible in the dark)
975	524	Red heat (visible in the daylight)
1292	700	Dark red
1472	800	Dull cherry red
1652	900	Cherry red
1832	1000	Bright cherry red
2190	1200	Lemon yellow
2300	1260	White
2500	1371	Welding heat (sparks fly)

Fig. 8-3. Colors for judging high temperature.

color closest to this temperature is a cherry red to a bright red, Fig. 8-3. Be sure to have the metal heated uniformly.

2. Quench the metal quickly in the correct cooling solution. Whirl the metal around in the solution so it will cool quickly and evenly, Fig. 8-4. Water is used for most tool steels. Temperature of water should be 60-80 deg. F (15.6-26.7 C).

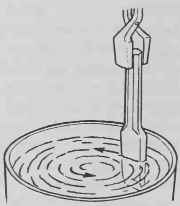


Fig. 8-4. Quenching heated steel. Whirl the metal in a circular motion, with a slight up and down movement at the same time.

3. Check the metal for hardness by running a new file across a corner or edge. If the metal is hard, the file will not cut in.

TEMPERING

The entire piece of metal can be tempered by heating it in a furnace to the temperature which will produce the degree of toughness and hardness desired, Fig. 8-5. Remove the piece and cool it quickly in the correct quenching solution.

To draw the temper on small tools such as center punches, screwdriver blades, or cold chisels, the following procedure may be used:

Deg. F	C	Color	Tools
430	221	Pale yellow	Hammer faces, Scribers, Scrapers
460	238	Straw yellow	Center punches
500	260	Brown	Cold chisels
540	282	Purple	Screwdrivers

Fig. 8-5. Tempering colors for common tools.

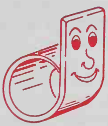
1. Harden the entire tool.
2. Polish about one inch of the surface at the cutting edge or point with abrasive cloth. This will make it easier for you to see the change of colors as the heat travels toward the point or cutting edge of the tool.
3. Heat the metal slowly and uniformly back of the polished surface. Watch carefully for the colors as they travel toward the hardened end. The colors generally appear in the following order--pale yellow, straw color, light brown, light purple, blue-red, blue, and finally gray.
4. When the proper color appears at the cutting edge or point, plunge the metal into the quenching solution quickly, and move it in a circular motion until completely cooled.
5. Check the tool for hardness by using it on a scrap piece of metal. If the piece chips, it is too hard and must be heated to a color of a slightly lower degree of hardness and cooled as before. If the point or edge bends under practical use, it is too soft and must be hardened and tempered again.

The Sand Box method is another way which can be used to temper small pieces. This is done by placing the hardened tool (polished as described in Step 2) in the sand with the point sticking out. Heat the sand in the bottom of the metal box. Watch the temper colors as they travel toward the point. When the correct color reaches the point, remove the tool with tongs and cool it quickly.

Hardening and tempering may be performed with one heat. This is done by heating the metal to the proper tempering temperature. Remove the tool from the heat, and quickly clean the point with abrasive cloth. Then insert the tool in the cooling solution and remove it quickly. Watch the colors carefully as they appear. When the proper color appears at the work end, quickly plunge the tool in the cooling solution and move it around in a circular motion, with a slight up and down motion. The up-and-down motion helps prevent fractures or checks at the line where the tool is placed in the cooling solution.

CASEHARDENING

1. Place the pieces to be casehardened in metal boxes or pipes.
2. Pour Kasenite (a nonpoisonous commercial compound) around them. Be sure the pieces are completely surrounded with the compound.
3. Place the lid on the box and put it in the furnace.
4. Heat box to about 1650 deg. F (899 C). Depth of casehardening will depend upon the length of time the part is kept hot. A depth of approximately 1/32 in. is obtained if the packed metal is held at above temperature for about four hours.
5. Remove the box from the furnace and allow it to cool without quenching.
6. Reheat the parts to 1600 deg. F (871 C) and quench in water. This will give the metal a hardened case and leave the core soft.



CHIP SAYS:

"When working with hot metal be careful not to burn yourself or another person. Always wear protective clothing."

Simple casehardening can be done by heating the metal to a bright red and placing it in a container filled with a commercial hardening compound. Roll or move the metal around in the compound. The compound will melt and adhere to the surface of the metal, forming a hard coating of steel around it. Reheat the metal to a bright red color and plunge it into clean, cold water. If a deeper case is desired, repeat the above steps.

The heat treating process is highly scientific and procedures vary with the many kinds of metals being used in industry. The heat treater must have a knowledge of chemistry and physics. Industries where foundry, forging, and machining of metal is done require the services of skilled heat treaters. Today most of the heat treating is automated; however, the technicians, engineers, and inspectors are responsible for obtaining the correct metal characteristics with the automatic equipment.

QUIZ – UNIT 8

1. Why is it necessary to heat treat a cold chisel?
2. List the three characteristics tools should have to do their work.
3. How is tool steel hardened?
4. Describe one method for drawing the temper on a center punch.
5. Three cooling solutions are ___________, ___________ and ___________.
6. Steel is magnetic until it reaches the ________ temperature.
7. Tempering tool steel removes a certain degree of ________ and ________.
8. Why does hardened steel have to be tempered for many tools?
9. Describe how tool steel is annealed.
10. Tempering always follows ___________ and ___________.
11. Why should the metal be moved in a circular motion in the cooling solution?
12. Can hardening and tempering be performed with one heat?
13. What is casehardening?
14. Are all steels of the water-hardening type?
15. The pack method of carburizing is a method used to ________ metal.

Unit 9
FOUNDRY

After studying this unit, you will know:
1. **Principal methods of casting metal.**
2. **Some of the characteristics of a good pattern.**
3. **How to make a core.**
4. **How to make a sand mold.**

Foundry is a vital process in the metal industry. Most of our metal products contain some cast parts. Founding produces metal objects by pouring molten (melted) metal into a hollow mold usually made of sand. These objects are called castings.

CAREER OPPORTUNITIES

Founding provides many jobs for unskilled, semi-skilled and skilled workers as well as for technicians and engineers. Engineers and metallurgists are responsible for quality of the metal used. Skilled woodworkers and metalworkers, called patternmakers, make mold patterns. Molders ram sand into molds. Coremakers produce special shapes that make cavities in a casting. A melter runs the furnace to prepare the metal. A pourer puts the molten metal into the mold. Chippers, grinders and finishers clean up the castings.

METHOD OF CASTING

Green sand casting is a foundry method generally used in school metals programs. Two types of foundry sand are commonly used:

1. Natural sand, a mixture of sand and clay.
2. Synthetic sand which has an oil binder and does not require water tempering.

The sand is rammed into a mold. Molten metal is poured into a cavity formed in the mold with a pattern. After the metal is hardened, the casting is removed. The sand is then ready to be reused.

Permanent molds are used for producing large quantities of identical pieces. These molds are made of steel and used primarily for casting nonferrous metals such as aluminum, brass, and bronze.

Investment casting, which is sometimes referred to as lost wax casting, is used for casting jewelry, dental structures and parts requiring very close tolerances. In the process a wax pattern is coated with an investment powder which hardens forming a shell around the wax. The wax is then melted out leaving a cavity into which the molten metal is poured.

Die casting is a method of casting nonferrous metals in which the molten metal is forced into a steel mold or die under pressure. Castings can be made quickly and economically on automatic machines by this method. Die castings can be produced with finer finish, detail, and greater accuracy than ordinary sand castings.

A foundry in the school shop provides a means for making many interesting projects such as wall plaques, ash trays, lamps, candlestick holders, parts for home workshop tools, and machines to mention a few. By using a little imagination and creative ability, you will be able to design and make some very useful projects in this area.

PATTERNMAKING

Patterns are needed to form the cavity in the sand mold into which molten metal is poured. They may be made of wood, metal, plaster of Paris, or wax. A metal pattern lasts longer and keeps its shape better. Metals commonly used are aluminum, cast iron, steel, and brass. Woods generally used for patterns are white pine, mahogany, cherry, maple, birch, and fir. White pine is usually preferred because it works easily, is readily glued, and is reasonably durable. Wood patterns should be varnished to protect them against moisture. Coloring powders can be added to the varnish to identify various parts of the pattern.

You can probably find many articles around your home which may be used as patterns for foundry work. Small trays, plaques, paper weights, book ends, etc. make good patterns providing they have enough draft to be pulled.

Draft refers to the taper on a pattern that makes it possible to remove it easily from the sand mold, Fig. 9-1. If a pattern does not have enough draft, the mold will break when the pattern is pulled. As a general rule each side should be tapered 1/8 in. for each foot of surface to be drawn. Fillets are used in sharp internal angles, Fig. 9-1. These fillets can be made of wax, leather, or wood.

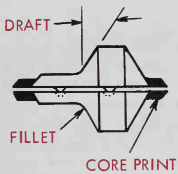


Fig. 9-1. Split pattern.

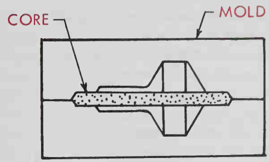


Fig. 9-2. Core in mold.

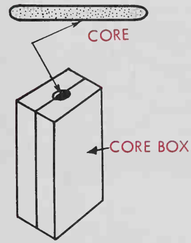


Fig. 9-3. Core box.

Metal takes up more space when it is hot than when it is cold. Therefore, the pattern must be made larger to allow for this shrinkage. For example, cast iron shrinks about 1/8 in. to the foot, so the rule in reality would be 12 1/8 in. long. The additional length is gradually gained in the length of the rule. The shrinkage allowance varies with the kind of metal being cast, and the size and shape of the casting. To compensate for this contraction of the castings in cooling, the following allowances are made: cast iron 1/8 in. per ft., yellow brass 7/32 in. per ft., aluminum 1/8 to 5/32 in. per ft. If the cast piece is to be machined, the pattern should be large enough to produce a piece that can be cleaned by leaving no rough spots or flaws after it has been cut to size.

CORES

A core is used in molding to form a hole or hollow space in a casting, Fig. 9-2. Cores are made from washed silica sand and a bonding material. The sand and binder is mixed until the binder is uniformly distributed in the sand. The core sand is molded to shape in a core box, Fig. 9-3. Core prints are provided on patterns to form recesses in the mold to support the core, Fig. 9-1. The core is then turned out onto a plate and baked in an oven. The oven temperature and baking time depends on the size of the core and the kind of binder used. The temperature and baking time should be controlled to produce a core with enough hardness and strength to withstand the flow of the molten metal as it is poured into the mold cavity around the core. Wires can be embedded in large cores to provide additional strength in sections requiring greater strength. Large cores should be vented to permit passage of mold gases. If the core has two or more parts that are to be assembled, they can be bonded together with a flour paste. To improve the surface smoothness, coat the core with a wash of either talc or graphite.

MAKING A SAND MOLD

1. Synthetic sand does not require water since it contains an oil binder. When using Natural sand you temper the sand by sprinkling it with a little water. Mix the sand with a shovel until all the lumps are broken up and it is uniformly moist.

Test the tempered sand by squeezing a lump in the palm of your hand. If properly tempered, the lump will break clean, leaving sharp impressions of your fingers. If the sand sticks to your hand it is too wet. Properly tempered sand is necessary to get good castings. If the sand is too damp when the melted metal is poured into the mold, steam will form faster than it can escape through the pores of the sand.

2. Place the drag half of the flask on a molding board with the pins pointing down, Fig. 9-4.

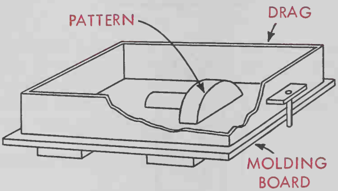


Fig. 9-4. Pattern and drag placed on molding board.

Place the pattern in the center with its flat side down on the board. Dust the pattern with just enough parting compound to cover its surface.

3. Set the riddle on top of the drag and fill it with sand. Riddle the sand over the pattern until it is covered 1 in. or more, Fig. 9-5.

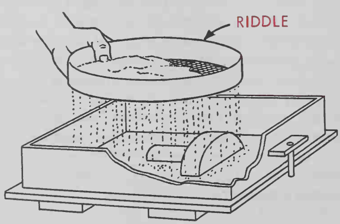


Fig. 9-5. Riddling molding sand over pattern.

4. Pour the rest of the sand left in the riddle into the drag. Shovel in more sand until the drag is heaping full.

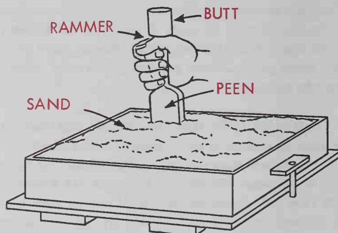


Fig. 9-6. Ramming the sand down in the drag and around the pattern.

5. Press the sand down in the drag and around the pattern with the peen end (small end) of the rammer, Fig. 9-6. The large end of the rammer is the butt. Be careful not to strike the pattern, or the edges of the drag. Ram the sand in firmly around the pattern and drag with the butt end. Properly ramming the sand is very important. If it is not rammed enough the sand may not be packed around the pattern firmly enough to give a good, sharp impression. If the sand is rammed too tightly the pores will not be large enough to allow the hot gasses formed in the mold to escape.

6. Strike off the excess sand on the top of the mold with a strike bar, Fig. 9-7. Sprinkle a handful of

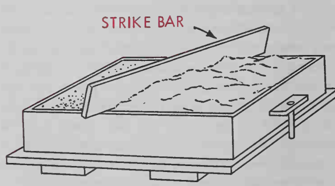


Fig. 9-7. Striking off excess sand with the strike bar.

sand over the mold and lay a bottom board on the top. Move the bottom board back and forth, pressing down at the same time, until it sets firmly against the edges of the drag.

7. Holding the mold board, drag, and bottom board

firmly, carefully roll the drag over. The pins are now pointing up, the bottom board is at the bottom and the molding board is on top.

8. Remove the molding board. The flat side of the pattern is now visible. Check the surface of the sand and smooth with the slick, spoon, trowel, and lifter if necessary, Fig. 9-8. Also be sure the sand is packed around the edges of the pattern. Carefully blow off any extra particles of sand.

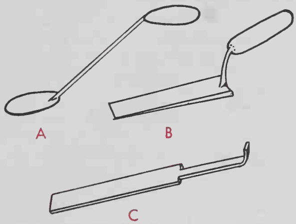


Fig. 9-8. Molders tools. (A) Slick and spoon; (B) Trowel; (C) Lifter.

9. Dust some parting compound over the pattern, and sand to keep the two halves from sticking together. Set the cope part of the flask on the drag, Fig. 9-9. Insert the sprue pin and riser pin.

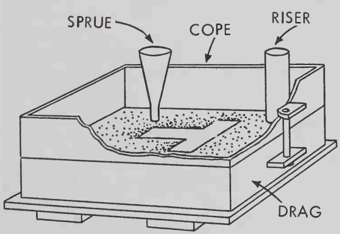
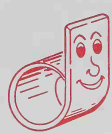


Fig. 9-9. Cope set on drag with riser pin and sprue pin in place.

The sprue pin is a tapered wooden or metal pin that is used to make a hole in the cope through which the metal is poured into the mold. The riser which has no taper, is used to make a hole for the metal to rise in and make up for some of the shrinkage when the metal cools.

10. Riddle sand into the cope, and ram as in Steps 3, 4, 5, and 6.
11. Vent the mold over the pattern so air, steam, and gas can escape as the molten metal is poured into the mold. This will help prevent the mold from exploding and keep blow holes (holes made by bubbles) from forming in the casting. A 1/16 in. welding rod slightly pointed on one end makes an excellent vent rod. Do not damage the pattern. A safe method is to push the vent rod into the mold slowly until it touches the pattern, and then pull it back about 1/4 in. Grip the vent rod at this level with your fingers. Punch several holes in the mold over the pattern, being careful to stop when the tips of your fingers touch the sand.
12. Remove the sprue pin and the rise pin. Shape the top of the sprue hole like a funnel, with your fingers. Be sure there is no loose sand around the sprue and riser holes.
13. Lift the cope section of the flask off and lay it on its edge. Carefully moisten the sand around the pattern with a camel's hair brush or wet bulb. This makes the sand around the pattern firmer, and keeps the mold from breaking when the pattern is removed.
14. Place a draw pin in the pattern. If the pattern is metal the draw pin has threads on one end that are screwed into a tapped hole in the pattern. A sharp pointed spike or a large wood screw may be used as a draw pin to remove a wood pattern. Rap the draw pin on all sides until the pattern is completely loose in the sand. Carefully and with a steady pull, lift the pattern straight up from the mold. If there is a little breaking off of the sand, repair it with a molder's tool.
15. Cut a small gate (channel) in the sand of the drag from the cavity made by the pattern to the place where the sprue is located. The width and depth of the gate will vary according to the size of the casting. The larger the casting, the larger the gate. For small plaques or book-ends, the gates should be about 1/2 in. deep and 1 in. wide. A piece of sheet metal 3 in. square, bent into a U-shape,



CHIP SAYS:

"Do not get the sand too wet. Water is an enemy of molten metal."

makes an excellent gate cutter. Cut away a little sand at a time until the gate is completed. Now cut a gate between the riser and the cavity. Patch up any small breaks that have occurred in the mold. Blow off all loose sand with the bellows. It is extremely important that all particles of loose sand are removed from the gates and cavity. Small particles of sand in the mold will cause the casting to have pinholes.

16. Carefully replace the cope section on the drag. Check to be sure the mold is completely closed. Place a flask weight on top of the mold to keep the molten metal from lifting up the sand. Set the mold on the floor. It is now ready to receive the melted metal.

To make a mold with a split pattern, follow the same steps as described above except that half of the pattern is rammed up first in the drag. After the molding board is removed the other half of the pattern is put in place on the half in the drag. The cope section of the flask is put in place and the steps described are followed. When molding a split pattern, the largest half of the pattern should be rammed up in the drag.

MELTING FURNACE

There are several kinds of furnaces for melting metal. Commercial foundries use cupola furnaces to melt large amounts of metal. In a school shop where only a small amount of casting is done a small melting furnace is used such as shown in Fig. 9-10. This furnace will melt aluminum, brass, and other light metals. Lead, tin, and some alloys can be melted in a large soldering furnace, forge, or with a gas welding torch. However, a melting furnace and a crucible is the safest and best method. The crucible can be used as the pouring ladle. Lifting tongs are used to pick up the crucible and place it in the crucible shank for pouring. Fig. 9-11, gives the melting points of common metals.

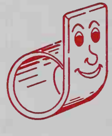
Fig. 9-10. Melting furnace. (Johnson Gas Appliance Co.)

Metal	Degrees Fahrenheit
Solder (50/50)	400
Pewter	420
Tin	449
Lead	621
Zinc	787
Aluminum	1218
Brass	1700
Silver	1761
Copper	1981

Fig. 9-11. Melting points of metals.

POURING THE METAL

1. Select a crucible which is large enough to hold enough metal to fill the cavity, sprues, and risers. Fill the crucible with the pieces of metal to be melted.
2. Place the crucible in the furnace. Light the furnace and heat until the metal reaches the pouring temperature. Do not overheat. Overheated metal will produce defective castings.
3. Turn the furnace off. First turn off the air, then the gas. Add flux (commercial fluxes are used for aluminum, brass, and other alloys) to purify the



CHIP SAYS:

"Dress properly when working with molten metal. Wear a pair of clear goggles, leggings, and asbestos gloves.

Never stand or look over the mold during the pouring or immediately after the pouring because the molten metal might spurt out of the mold.

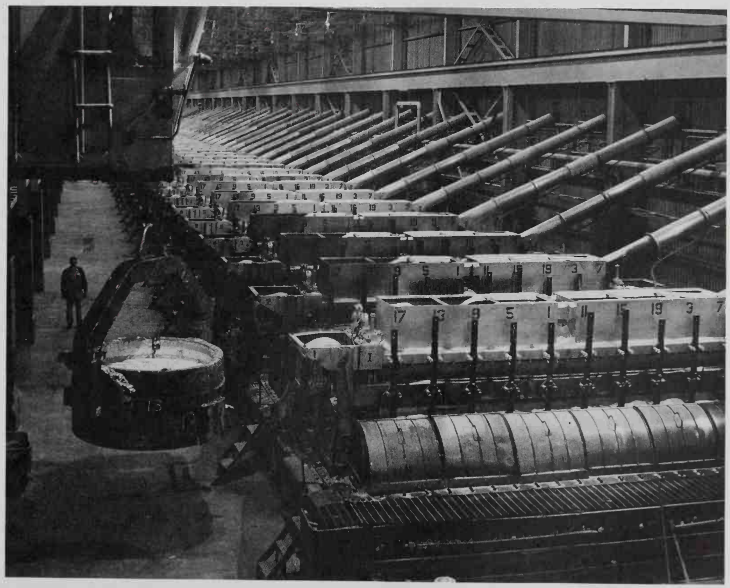
Do not light the furnace until you have your teacher's permission. If cold metal must be added to melted metal, be sure it is perfectly dry, and that tongs used are also perfectly dry, or an explosion will result."

metal. Stir the metal to bring the impurities to the top. Skim off the impurities (called slag).

4. Remove the crucible from the furnace with the crucible tongs, and place it in the crucible shank. Pick up the crucible shank so you are in a comfortable position. Stand to one side of the mold and pour the metal as quickly as possible into the mold in a steady stream. It must be poured rapidly enough to keep the gate and sprue full until the mold is filled.
5. After the metal has cooled, shake out the mold and remove the casting. The casting may still be hot so handle it with tongs.

QUIZ — UNIT 9

1. List four jobs in commercial foundry work and describe each one.
2. List the principal methods of casting metal.
3. Name five kinds of wood used for pattern-making.
4. What is meant by "draft?"
5. Give two reasons why pattern must be larger than finished casting.
6. What is the purpose of a core?
7. What is the purpose of "core prints?"
8. What is a flask?
9. What is the difference between the drag and the cope?
10. How is molding sand tempered?
11. Describe the purpose of the riser and the sprue.
12. What is the purpose of the gate?
13. Why is parting compound dusted on the pattern?
14. How should you be dressed when pouring molten metal?
15. Why is water an enemy of molten metal?



Overhead crane moves crucible of molten aluminum which has just been tapped from the electrolytic cells, or pots, in this potline. (Kaiser Aluminum & Chemical Corp.)

Unit 10
MACHINE SHOP

After studying this unit, you will know:
1. How to use measuring tools to take accurate measurements.
2. How to machine metal on the lathe.
3. Information about the metal shaper and milling machine.

The machine shop plays an important role in the field of industry. Machine tools cut and shape metal more rapidly and more accurately than can be done by hand. The progress of industrial manufacturing and mass production depend upon machine tools. A skillful craftworker in metalwork should acquire an understanding of machine shop processes, and particularly the ability to work with accuracy and close tolerances.

CAREER OPPORTUNITIES

There are many opportunities in the machining occupations for the bright and ambitious person. A skilled machinist is always in demand. There are thousands of machinists employed in skilled and semi-skilled machining occupations which include machine tool operators, all-around machinists, tool and diemakers, setup workers and layout workers. Tool and diemakers are highly skilled craftworkers in the metalworking field. They must be able to operate machine tools and use precision measuring instruments. Other requirements include a knowledge of mathematics, blueprint reading and machine operations.

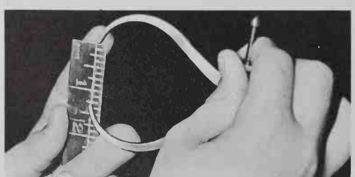


Fig. 10-1. Setting an outside caliper.

MEASURING TOOLS

Measuring carefully and accurately is essential to good machine work. As a beginning machine shop student, you will want to learn to take accurate measurements with some of the basic devices used by the machinist. Some information on measuring tools was given in Unit 4. In this Unit we will discuss Inside and Outside Calipers, and the Micrometer.

OUTSIDE CALIPER

This tool is used to take external measurements of cylindrical stock. To set an outside caliper, hold the instrument in the right hand and a scale in the left hand, Fig. 10-1. One leg of the caliper is supported against the end of the scale with a finger. Adjust the other leg until it splits the line on the scale which represents the correct measurement. To take a measurement, hold the caliper at right angles to the center line of the work and push it gently back and forth across the diameter of the cylinder to be measured, Fig. 10-2. The caliper is properly adjusted when it will slip over the piece with a very slight drag. Do not force the caliper over the work since this will spring the legs and the measurement will not be accurate.

INSIDE CALIPER

An inside caliper is used to gage inside diameters. To set an inside caliper for a desired dimension, hold a scale square on a flat surface. Then rest one leg of the tool on this surface at the edge and end of the scale. Adjust the other leg until it centers the proper graduation on the scale, Fig. 10-3. To take a measurement with an inside caliper, place it in the hole as indicated in Fig. 10-4. Adjust the caliper until

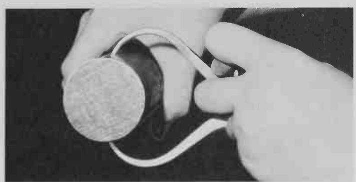


Fig. 10-2. Taking a measurement with an outside caliper.

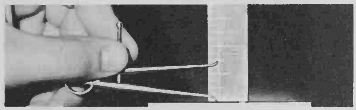


Fig. 10-3. Setting an inside caliper.

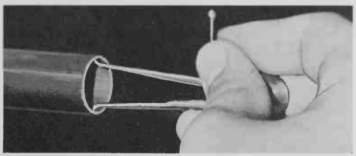


Fig. 10-4. Taking a measurement with an inside caliper.

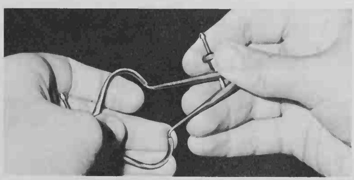


Fig. 10-5. Transferring measurements.

it will slip into the hole with a very slight drag. To transfer measurements from an inside caliper to an outside caliper or vice versa, rest the point of one leg of the inside caliper on the point of an outside caliper, Fig. 10-5. Pivot the top point of the inside caliper in and out of the top point of the outside caliper. Adjust the thumb screw until the leg drags slightly as it contacts the leg of the outside caliper.

MICROMETER

A micrometer is a precision measuring tool which is used by the machinists. They call it a "mike." Micrometers are made in different sizes and styles. The outside mike which will be described in this unit resembles a C clamp, Fig. 10-6. It has 40 threads per

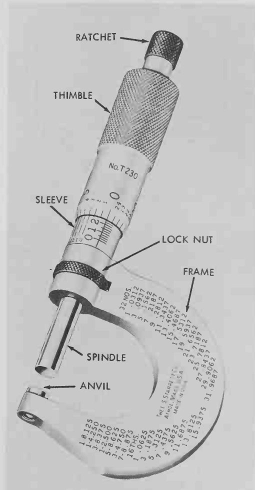


Fig. 10-6. Parts of a micrometer. (The L. S. Starrett Co.)

inch on the screw. One complete turn of the thimble moves the spindle 1/40 in. or 0.025 in. The thimble is marked off in 25 equal parts, each of which is 1/1000 in. or 0.001. On the sleeve there are 40 lines to the inch. Every four divisions on the sleeve are marked 1, 2, 3, etc., which represents 0.100, 0.200, 0.300 in., etc.

READING THE MICROMETER

1. Turn the thimble until the spindle is closed against the anvil. The reading should be zero with

the 0 mark on the thimble directly over the 0 mark on the sleeve.

2. Back off the thimble slowly. As each mark on the thimble passes the horizontal line on the sleeve the micrometer has been opened 0.001 in. When the thimble has been backed off one complete turn, 25 of these marks have passed the horizontal line on the sleeve and the micrometer has been opened 0.025 in.
3. To read the micrometer, first take the reading on the sleeve and then add to it the reading on the thimble. For example in Fig. 10-7, you can see

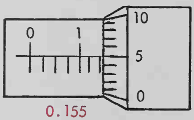


Fig. 10-7. One hundred fifty-five thousandths of an inch (0.155).

two divisions past the 1 on the sleeve, or six full divisions. The thimble reading is 5. Your reading would be 0.155 in. (0.025 in. x 6 = 0.150 in. + .005 in. = 0.155 in.) Study Fig. 10-8 and see if you can read the micrometer settings.

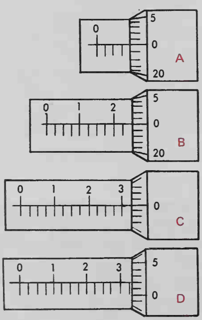


Fig. 10-8. "Mike" readings. (A) One hundred thousandths of an inch (0.100); (B) Two hundred fifty thousandths of an inch (0.250); (C) Three hundred twenty-five thousandths of an inch (0.325); (D) Three hundred twenty-seven thousandths of an inch (0.327).

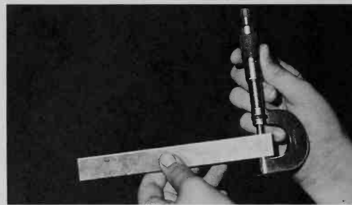


Fig. 10-9. Taking a measurement with a micrometer.

After you learn to read the mike, practice using it by measuring some pieces of stock. When using the mike, hold it in the right hand and screw the thimble down until it lightly touches the stock, Fig. 10-9. Be careful not to screw it down too tight. Take the reading. Back the spindle off the stock and remove the mike and put it in a safe, clean place. Do not mike a piece of metal while it is turning in the lathe. Never tap a micrometer against other objects or drop it, since this may destroy its accuracy.

THE METAL LATHE

A metal lathe is used to cut and shape metal by revolving the piece against a cutting tool which is clamped on a movable carriage mounted on the lathe bed. They are used to perform many processes, including turning down metal rods, facing, cutting off, turning tapered sections, cutting threads, drilling, and boring.

The principal parts of the lathe include the headstock, tailstock, bed, carriage, and the feeding and threading mechanisms, Fig. 10-10. After you become familiar with the names and location of the various parts of the lathe, get permission from your teacher to move the different handles and levers by hand, with the power off, to see what they do. All parts should move easily, never force them.

TURNING BETWEEN CENTERS

1. Carefully locate the center on both ends of the stock to be turned. The center of round stock may be located using the centerhead of the combination set, Fig. 10-11. Rectangular and square pieces are easily centered by drawing diagonal lines, Fig. 10-12.

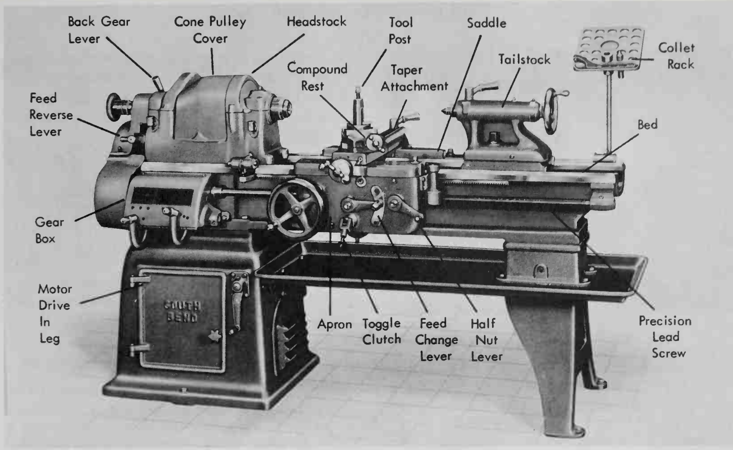


Fig. 10-10. Principal parts of a metal lathe. (South Bend Lathe)

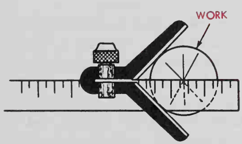


Fig. 10-11. Locating the center of round stock.

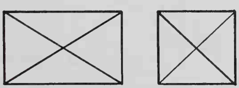


Fig. 10-12. Locating the center of square and rectangular stock.

2. Center punch the center point on each end of the stock.
3. Check the alignment of the lathe centers, Fig. 10-13. The live center should run true. Carefully bring the dead center to within 1/16 in. of the live center. If the points of the two centers are not in line, move the tailstock over by adjusting the setover screws, Fig. 10-14.
4. Remove live center and replace it with a drill chuck, Fig. 10-15. Fasten a combination drill and countersink in the chuck, Fig. 10-16.

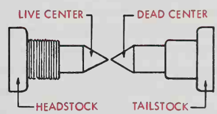


Fig. 10-13. Checking alignment of lathe centers, looking from above.

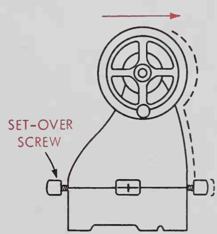


Fig. 10-14. Setting tailstock.

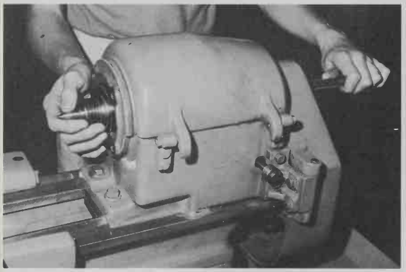


Fig. 10-15. Remove live center from headstock with a knockout rod. Hold the center so it will not fall and damage the point.

Fig. 10-16. A combination drill and countersink. (Cleveland Twist Drill Co.)

5. Move the tailstock to such a position that the work just fits between the point of the drill and the dead center, and clamp the tailstock in place.
6. Put the center punch mark of one end of the stock on the drill point. Holding the work piece steady, turn the tailstock wheel to bring the dead center into the other center punch mark carefully, Fig. 10-17.

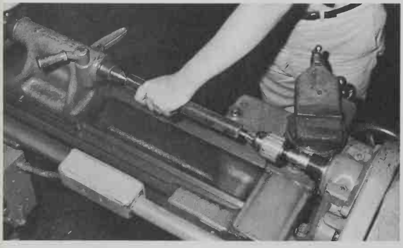


Fig. 10-17. Center drilling on the lathe.

7. Apply lard, oil or cutting compound to drill when drilling steel. Cast iron should be drilled dry.
8. Hold the work with the left hand and start the lathe and feed by turning the tailstock spindle handwheel slowly until the center hole is drilled to the correct size, Fig. 10-18. Reverse the work

Fig. 10-18. Center drilled holes. (A) Properly drilled; (B) Drilled too deep.

in the lathe and drill the other end.

9. Remove the drill chuck and screw a faceplate on the headstock spindle. Clean and oil the threads of the headstock spindle and faceplate. Place a board across the ways of the lathe and screw the faceplate onto the spindle until it is tight against the shoulder. Never bring the faceplate against the spindle shoulder with a bang since this will make it difficult to remove.
10. Clean out the spindle hole with a rag and insert the live center.
11. Clamp the smallest size lathe dog that will fit on one end of the work piece.
12. Place a small amount of white lead lubricant in the center hole at the tailstock end. Insert the work between the centers and screw up the tail center just snug enough to prevent the lathe dog from chattering when machine is in operation, Fig. 10-19.

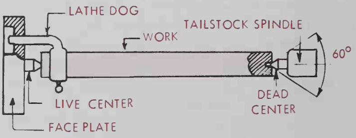


Fig. 10-19. Work mounted between centers.

13. Choose the proper lathe tool cutter bit for the job, Fig. 10-20.
14. Insert the tool holder in the tool post. Insert the cutter bit in the tool holder and tighten. Adjust

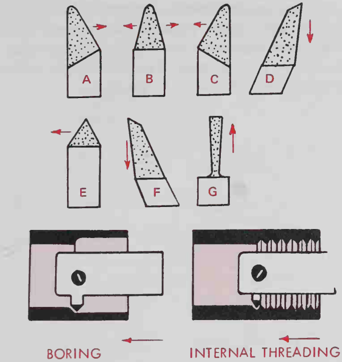


Fig. 10-20. Common lathe cutting tools. (A) Left-hand turning tool; (B) Round-nose turning tool; (C) Right-hand turning tool; (D) Left-hand facing tool; (E) Threading tool; (F) Right-hand facing tool; (G) Parting or cut-off tool.

the cutter bit and tool holder so the cutting edge of the tool is at the height of the lathe centers or a little above as shown in Fig. 10-21.

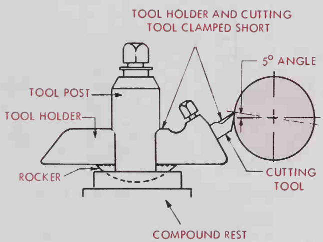


Fig. 10-21. Tool holder and cutting tool properly adjusted.

15. Adjust the lathe for the proper speed and feed. The cutting speed varies for different metals and for different sizes of stock. Feed is the distance the carriage, carrying the cutting tool, travels along the bed with each revolution of the spindle. Fig. 10-22 gives the cutting speed and feed for some of the more common metals.

Dia. in Inches	Cast Iron 75 f.p.m.	Machine Steel 100 f.p.m.	Soft Brass 200 f.p.m.	Aluminum 300 f.p.m.
1	287	382	764	1146
2	143	191	382	573
3	95	127	254	381
4	72	95	190	285
5	57	76	152	228
6	48	64	128	192
7	41	55	110	165
8	36	48	96	144
9	32	42	84	126
10	29	38	76	114

Fig. 10-22. Spindle speeds in revolutions per minute for average cuts with high-speed steel cutter bits.

16. The cut should be from the tailstock toward the headstock so the pressure is on the live center which turns with the work. Start the lathe and screw the cutter bit into the stock to take a cut. Engage the power fed and make the cut.
17. Check to see if the live and dead centers are in alignment as follows: After a complete cut has been made on the diameter and length of the stock, measure both ends with a micrometer. If the measurement is the same at both ends the centers are aligned. If the measurements are different, adjust the tailstock set-over screws and take another cut. Repeat these operations until both ends measure the same.
18. Adjust an outside caliper to 1/32 in. over the finished size. Turn on the lathe and turn the cross-feed handle to move the cutter bit into the work for a roughing cut that will true up the stock. Make a trial cut about 1/4 inch wide.
19. Turn the power off and check the trial cut with the calipers. Two or more roughing cuts may have to be taken.
20. Turn on the power and cut a little past the halfway point on the length of the stock. Continue cutting until the stock has been cut to within 1/32 in. of finished diameter. Remove the lathe dog and place it on the other end of the stock. Place the stock in the lathe and cut the other end to within 1/32 in. of the finished size.
21. Place a finishing cutter bit in the tool holder and make a trial cut about 1/4 in. long. Do not change cross-feed setting. Mike the cut. If the diameter for example, is .004 in. oversize, turn the cross-feed micrometer collar .002 in. in and take another trial cut. Check the diameter again with the mike. If the diameter is correct, make the longitudinal cut a little past the center.

22. Do not change the cross-feed setting. Remove the lathe dog. Place a band of aluminum or copper about 1/2 in. wide around the other end of the stock to protect the finished surface from the lathe dog screw. Slip the lathe dog over the soft metal band and clamp it in place.
23. Cut the other half of the stock to the finished size. When turning work to two or more diameters, cut the largest diameter first. Mark the stock at the first shoulder and cut this diameter. Continue this procedure until the smallest diameter has been turned.

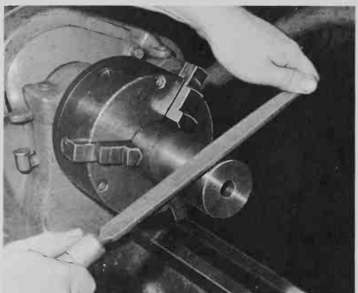


Fig. 10-23. Filing in the lathe. Keep the left arm well above the revolving chuck.

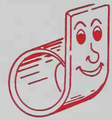
FILING AND POLISHING

Tool marks can be removed and a smooth, bright finish can be obtained on the surface of a piece by filing and polishing, Fig. 10-23. Use a fine mill file or a long-angle lathe file, Fig. 10-24. Adjust the lathe so

Fig. 10-24. A long-angle lathe file. (Nicholson File Co.)

that the work will make two or three revolutions for each stroke of the file. Take long, even strokes across the metal. File just enough to obtain a smooth surface. Always keep your file clean and free from chips with a file card.

A very smooth, brightly polished finish can be obtained by using fine grades of abrasive cloth after filing. Apply oil on the emery cloth and adjust the lathe to run at high speed. Keep the abrasive cloth moving slowly from one end to the other.



CHIP SAYS:

"Keep your sleeves rolled up and hold your left elbow high so it will not be hit by the revolving lathe dog. Be careful not to let the emery cloth wrap around the revolving work."

TURNING A TAPER

Short tapers, such as those on a lathe center or center punch can be turned by clamping stock in a lathe chuck and setting the compound rest to the desired degree of taper. The point of the cutter bit is set on center and the carriage is locked in place. Make the cut by turning the compound rest feed screw, Fig. 10-25. Cut length is limited to compound rest travel.

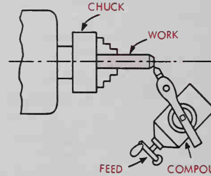


Fig. 10-25. Using the compound rest to cut a taper.

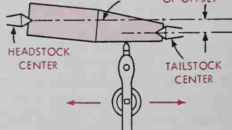


Fig. 10-26. Tailstock off-set to cut a taper.

Long tapers are turned by off-setting the tailstock, Fig. 10-26, or by means of a taper attachment. To find the amount of tailstock set-over for a taper, use this formula:

$$\text{Set-over} = \frac{\text{total length}}{\text{length to be tapered}} \times \frac{\text{large diameter minus small diameter}}{2}$$

When the taper per foot is known use this formula:

$$\text{Set-over} = \frac{\text{taper per foot, in inches}}{2} \times \frac{\text{length of piece}}{12}$$

LATHE CHUCKS

Lathe chucks are used to hold work that cannot be mounted between lathe centers. There are many machining operations which can be performed on work held in a chuck, such as turning, threading (internal and external), boring (straight and taper), reaming, and cutting off stock.

There are several types of chucks used for machining, the most popular being the 4-jaw independent chuck and the 3-jaw universal chuck, Fig. 10-27.

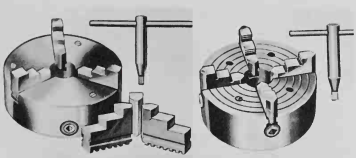


Fig. 10-27. Lathe chucks. Left, 3-jaw universal chuck. Right, 4-jaw independent chuck. (South Bend Lathe)

The 4-jaw independent has four reversible jaws which can be independently adjusted. It will hold round, square and irregular shapes. The work can be adjusted to practically any degree of accuracy required. The 3-jaw universal chuck will hold round and hexagonal stock. The jaws move in or out together and automatically center the work within about three thousandths of an inch. This chuck is usually provided with one set of jaws for outside chucking, and another set for inside chucking. The jaws cannot be reversed. The 3-jaw universal chuck is not used where extreme accuracy is required.

USING LATHE CHUCKS

When mounting a chuck on the lathe spindle, thoroughly clean and oil the threads of the spindle and the chuck back. A very small chip or burr will prevent the chuck from running smoothly. Remove the live center by holding the center with your right hand and giving the center a sharp tap with the knock out bar through the spindle hole. Place a piece of wood across the ways of the lathe to protect them. Grip the chuck by placing your fingers in the center between the jaws, and lift it onto the piece of wood. Turn the headstock spindle with the left hand and guide the chuck onto the thread. Be sure to get the chuck started squarely on the threads. The chuck should screw on easily. Continue to screw the chuck onto the spindle by hand until it is tight against the shoulder. Never bring the chuck against the spindle shoulder with a bang since this will make it difficult to remove.

To remove a chuck from the lathe spindle, engage the back gears and place a wood block between a chuck jaw and the back ways of the bed. Turn the spindle pulley by hand to loosen the chuck. Then place a board across the ways under the chuck. Continue to screw the chuck off by hand.

To mount the work in a 4-jaw independent chuck, open the four jaws an equal distance from the center. Use the concentric rings on the face of the chuck as a guide. Insert the work and tighten the jaws until it is approximately centered and held firmly. The work is then centered more accurately by bringing a piece of chalk in contact with the work as the chuck is slowly rotated, Fig. 10-28. The jaw opposite the chalk mark

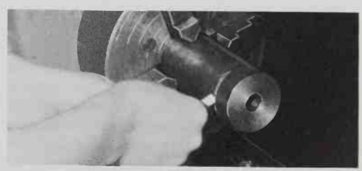


Fig. 10-28. Centering work by the chalk method.

is loosened slightly. Then tighten the jaw on the side where the chalk mark is located. Continue this procedure until the work is centered. Check all four jaws to be sure they are securely tightened before starting to machine the work.

To mount work in a 3-jaw universal chuck, open jaws until the work can be inserted. Then tighten jaws with chuck key. Be sure to remove the key.

FACING

The term facing refers to the cutting or squaring of the end of a piece of work, as in Fig. 10-29. The cutting tool is set so the cutting edge passes through the center of the work. Roughing cuts are made from the outside of the work toward the center. Finishing cuts are made from the center to the outside. Lock the carriage in place when making facing cuts.

Fig. 10-29. Facing in the lathe.

DRILLING

Drilling on the lathe is done by holding the work in the lathe chuck and securing the drill in the tailstock, Fig. 10-30. After the work has been faced, spot the center for the drill with the cutter bit. Adjust the lathe to the correct speed for drilling. Select a drill 1/64 in. undersize to allow for reaming. Insert the drill in the tailstock. Drills with straight shanks are chucked in a drill chuck that has a tapered shank which will fit the taper in the tailstock. Bring the tailstock close to the work, so the tailstock spindle will not have to be run out any farther than necessary to drill the hole. After the hole has been drilled, hand ream it in the lathe, Fig. 10-31. If a large hole is to be drilled, it is good practice to drill a pilot hole first.

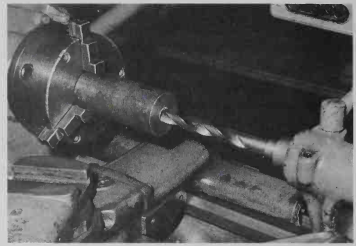


Fig. 10-30. Drilling in the lathe with a taper-shank drill. The drill is held in a drill chuck if it is a straight-shank.

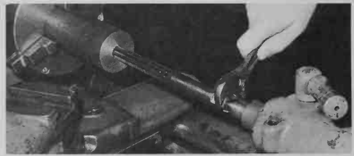


Fig. 10-31. Hand reaming in the lathe. Do not use power when hand reaming.

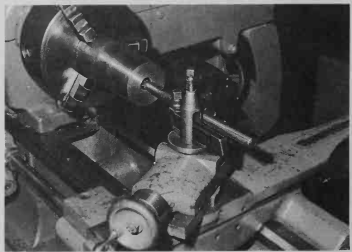


Fig. 10-32. Boring in the lathe with a boring bar.

BORING

Boring is done when the hole to be cut is not standard size, or to cut a very accurate hole. Use a boring tool holder with a bar which can be adjusted, so the cutting edge of the tool is in the proper position for cutting, Fig. 10-32.

THREADING

A lathe may be used to cut a great variety of threads. This is done by using a specially sharpened tool bit. The power feed is adjusted to move the carriage along at a rate that will cause the tool to cut the required number of threads per inch. This is a very fascinating operation. Ask your teacher for a demonstration.

An easy method for cutting internal threads, although not as accurate, is to use a tap in a lathe. Place the center hole of the tap on the point of the dead center and the work end of the tap in the (tap) drilled hole of the work, Fig. 10-33. Adjust the

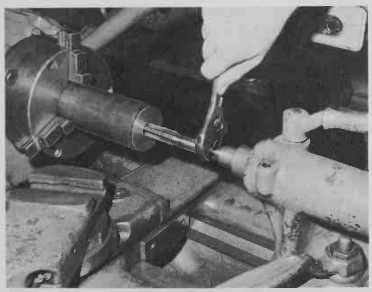


Fig. 10-33. Tapping in the lathe.

tailstock so there is just enough pressure to hold the tap in place. Turn the tap with a cresent wrench. After each turn of the tap it will be necessary to readjust the tailstock center. It is not necessary to complete the job in the lathe. After the threads have been started straight with the taper tap, the threading can be completed at the bench with the plug and bottoming tap.

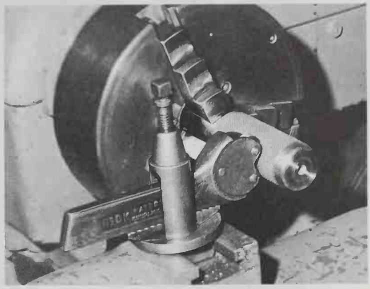


Fig. 10-34. Using lathe for knurling.

KNURLING

Knurling is a process of embossing the surface of the work, Fig. 10-34. Some pieces of work and handles of tools are knurled to provide a better gripping surface. Knurling tools are available which will produce fine, medium, coarse, straight, and diamond patterns.

The knurling tool is clamped in the tool post at right angles to the work. Adjust the lathe for the slowest back geared speed. Mark off the space to be knurled. Start the lathe and force the knurling tool into the work at the right end. The knurls should be pressed hard into the work at the start and then the pressure is relieved a little after making sure they track. <u>Use plenty of oil to lubricate the knurling wheels regardless of the kind of material being knurled</u>. Then engage the longitudinal feed of the carriage and let the knurling tool feed across the work to the left. To make a deeper cut reverse the lathe spindle and let the knurling tool feed back to the starting point. Do not remove the knurl from the impression. Force the tool deeper into the work, and let it feed back across the work. Repeat this procedure until the knurling is finished.

THE SHAPER

The shaper is a machine tool which has the cutting tool mounted in a ram, Fig. 10-35. The ram moves back and forth horizontally across the work. This machine can be used for shaping horizontal, vertical,

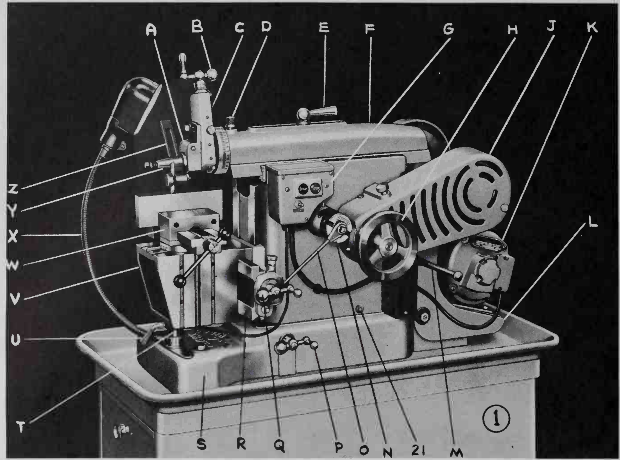


Fig. 10-35. Principal parts of a shaper: (A) Clapper box, (B) Down-feed handle, (C) Head, (D) Headswivel lock screw, (E) Ram clamping handle, (F) Ram, (G) Switch box, (H) Hand wheel, (J) Drive-pulley guard, (K) Motor, (L) Motor cradle, (M) Tension release lever, (N) Eccentric, (O) Feed rod, (P) Table elevating crank, (Q) Cross feed crank, (R) Cross-rail, (S) Base, (T) Work-table support, (U) Support locking handle, (V) Work-table, (W) Vise, (X) Lamp, (Y) Tool post, (Z) Tool holder. (South Bend Lathe)

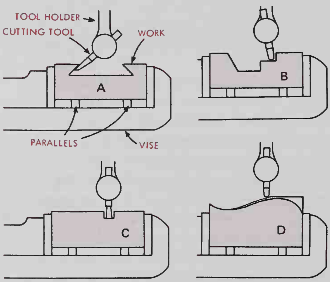


Fig. 10-36. Cuts that can be made on a shaper: (A) Angular cuts; (B) Horizontal; Vertical, and Angular cuts; (C) Slotting cut; (D) Simple form cutting.

angular and curved surfaces, Fig. 10-36. The work is either mounted in the vise, or clamped to the table. The table can be moved vertically or horizontally. The shaper size is determined by the maximum stroke in inches, such as 7 in., 12 in., 16 in., and 24 in. Except for some of the tool angles, the shaper

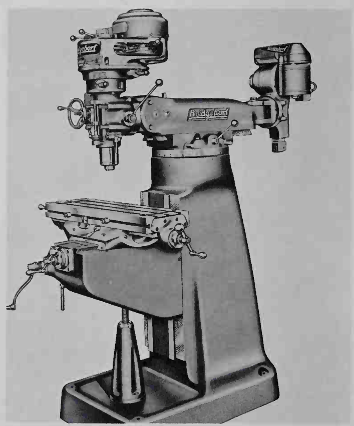


Fig. 10-37. Vertical milling machine. (Bridgeport Machines, Inc.)

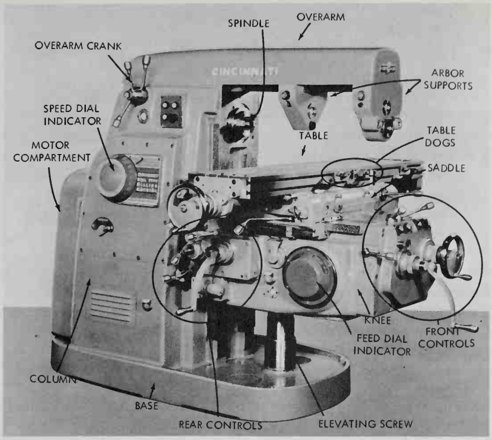


Fig. 10-38. Horizontal milling machine. (Cincinnati Milling Machine Co.)

cutting tools are the same as those used in the lathe. Since the shaper cuts on the forward stroke only, the side-relief angle needs to be only about 3 or 4 degrees. The end-relief angle, or front clearance, should be approximately 3 or 4 degrees.

THE MILLING MACHINE

The milling machine produces one or more machined surfaces on the work. The work is clamped to the table of the machine, or held in a fixture or jig which is clamped to the table. A rotating cutter shapes and smoothes the metal. There are several types of milling machines. The two most commonly found in the school shop are the Vertical Milling Machine, Fig. 10-37, and the Plain Horizontal Milling Machine, Fig. 10-38. These machines are known as knee-and-column type because the spindle is fixed in the column. The table (which is a part of the knee) can be adjusted longitudinally, transversely and vertically. Milling machines can be used to cut straight or irregular surfaces, slots, and grooves. They can also be used to cut gear teeth. Some milling operations are shown in Fig. 10-39 and Fig. 10-40.

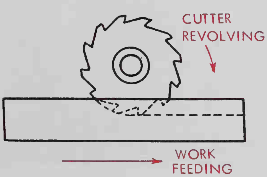


Fig. 10-39. Milling a slot in a block of metal.

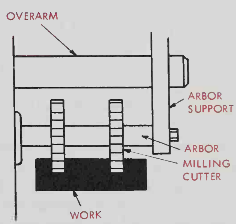


Fig. 10-40. Gang milling---cutting two slots in a block of metal.

NEW METAL FORMING TECHNIQUES

The development of super-tough alloys and the requirements of the space-age production line has brought about many new techniques for doing special

jobs. Several of these new methods are described in the paragraphs that follow. You will probably want to study these techniques in more depth if you are planning to pursue a career in the metalworking field.

EXPLOSIVE FORMING

This is a technique used to shape sheet metal. Although it was first used to shape small parts, today this method is used to make aerospace components. Existing presses are either too small or they do not have the power needed to fabricate the high-strength space-age metals. Another advantage of explosive forming is that no welded joints are required. This process makes use of a pressure wave which is generated by an explosion in a fluid. The pressure wave forces the walls of the metal being shaped against the walls of the die.

ELECTROCHEMICAL MILLING

This process shapes metal by removing part of the metal by deep etching. The amount of metal removed can be controlled and held to close tolerances. The technique makes it possible to shape metal parts that would be most difficult to do using conventional machining methods. Parts are immersed in an etching solution. A maskant (resistant material) is used to cover any surface not to be machined. The amount of metal removed is controlled by the length of time it is immersed.

ELECTRICAL DISCHARGE MACHINING

This is the process of removing metal by high current, low-voltage electrical spark (arcing) discharge which takes place between the tool and the metal being machined. The electrode, which is the shape to be cut, and the workpiece are submerged in a dielectric fluid during the machining process. This technique has the following advantages: metals that have been heat-treated can be machined. Also, fragile, hard, tough, heat sensitive metals that would be difficult to machine by conventional methods can be worked to close tolerances.

LASER MACHINING

This process is used in machining, cutting, and welding operations. A narrow and intense beam of light is produced by the laser. This beam of light can be focused optically into an area which is a few microns (thousandths of a millimeter) in diameter. Temperatures up to 75,000 deg. F (41,650 C) can be created instantaneously at the point of focus. Because of this intense heat, the laser beam can penetrate any material. Use of the laser is being researched not only in metalworking but in many areas, including the field of medicine.

OTHER TECHNIQUES

There are several other techniques which you may want to research and write reports for additional credit. These include magnetic forming, ultrasonic machining, electron beam machining, spark forming, and gas forming. You will find these techniques provide some interesting, unique methods which industry is using to form metal.

QUIZ — UNIT 10

1. The tool and diemaker must have a knowledge about ________, ________ and ________.
2. An outside caliper is used to take ________, ________.
3. An inside caliper is used to take ________.
4. If the reading on the micrometer sleeve is two divisions past the one and the thimble reading is 15, the reading would be ________.
5. What is a metal lathe?
6. A combination drill and countersink is used to ________ for ________ turning.
7. For very accurate turning you should use the ________ chuck.
8. Name two ways to turn tapers in a lathe.
9. List five operations that can be performed in a lathe.
10. Describe the use of a shaper.
11. What is the difference between a vertical mill and a horizontal mill?

Unit 11
COMPUTER AIDED MANUFACTURING

After studying this unit, you will know:
1. What is computer aided manufacturing.
2. How computer aided manufacturing developed.
3. How CAM will affect workers in the future.

Metalworking is a large part of our manufacturing industry. Up until about 1950, metalworking was accomplished by hand or standard machine tools, Fig. 11-1. Many industries still make use of these skills. Today, however, the manufacturing industry is moving rapidly to automate itself. Automatic machines take raw materials and produce finished products with little or no input from machine operators, Fig. 11-2.

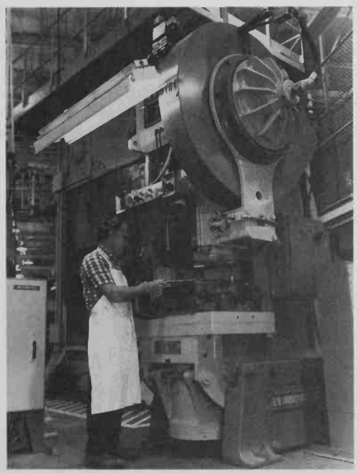


Fig. 11-1. Standard machine tools played a large part in manufacturing up through the 1950's.

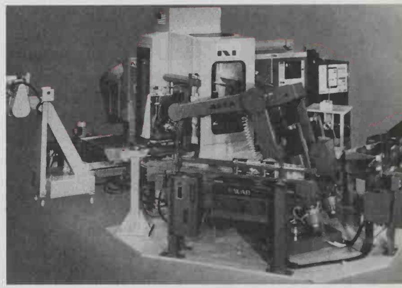


Fig. 11-2. A manufacturing "cell" consists of a group of flexible machines linked with robotics. (Kearney-Trecker)

WHAT IS COMPUTER AIDED MANUFACTURING?

Computer Aided Manufacturing (CAM) is the use of computer systems to plan, manage, and control the operations of manufacturing. When combined with the design of products (Computer Aided Design or CAD) Fig. 11-3, the total process is known as CAD-CAM. This is sometimes referred to as CIM (Computer Integrated Manufacturing).

THE DEVELOPMENT OF COMPUTER AIDED MANUFACTURING

The automation of modern manufacturing occurred in five steps. It started when James Watt invented the steam engine in 1760. This engine became the source of INDUSTRIAL POWER.

Fig. 11-3. Designing a part with the aid of Computer Aided Drafting.

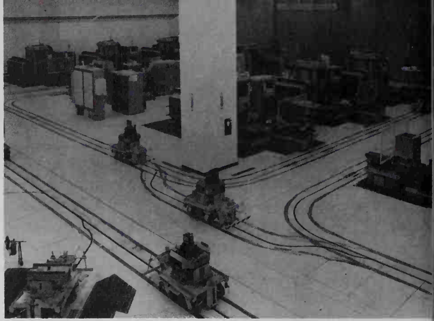


Fig. 11-5. Computer numerical controlled (CNC) machines are fast becoming a part of modern manufacturing. (Kearney-Trecker)

Factories no longer needed to be located near a river for water power.

A second step toward automation occurred about 1800 when Eli Whitney (inventor of the cotton gin) manufactured rifles for the government. He introduced the idea of INTERCHANGEABLE PARTS. A number of parts for gun barrels, triggers, hammers and firing pins were made. These parts were then placed in bins and the rifles were assembled using the interchangeable parts. The use of identical parts reduced the machining and assembly time.

Around 1910, Henry Ford introduced the third step, the ASSEMBLY LINE in manufacturing the "Model T" Ford car. The auto frame was placed on the assembly line and parts were added along the line. A car, complete with motor and wheels, rolled off the end.

The fourth stage in the movement toward the automated factory occurred around 1950. Parts were produced on machines that were controlled by punched or magnetic tape rather than human operators, Fig. 11-4. These tapes controlled the machine functions by a numerical language called NUMERICAL CONTROL (NC).

The latest step in the automated process is the COMPUTER. The computer makes lightning fast mathematical calculations necessary to control, adjust, and monitor machine processes. In the ultimate factory, only automated machines and robots will be on the plant floor, Fig. 11-5. Humans will be in the control centers monitoring the production and maintaining equipment.

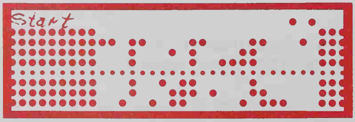


Fig. 11-4. Perforated tape which contains "numerical language" to control machines.

HOW DOES CAM WORK?

The computer has no intelligence of its own. It is only an extremely fast mathematical machine. It is controlled and directed by SOFTWARE programs which are designed by human beings. Once the program is designed, the computer controlled machine carries out its machining tasks with precision.

CAM AND THE FUTURE

There will be fewer workers on the production floors of manufacturing plants in the future. More workers will be involved in the design of the product and in planning the automated processes used to manufacture the product.

QUIZ — UNIT 11

1. Tell, in your own words, how manufacturing has changed over time.
2. Describe the Computer Aided Manufacturing process.
3. How does CAM change what workers do in manufacturing?
4. What will be required of future manufacturing workers?

Unit 12
METALWORKING PROJECTS

The projects covered in this Unit are examples of what can be constructed to assist you in your study of the various units of metal work. Your instructor may also have other projects which you will want to consider. You can also get ideas for additional projects by visiting gift shops and department stores and from magazines and catalogues.

The projects illustrated in this unit have been selected to provide easy ones for the beginning metalworking student to construct. Others which are more difficult to make have also been included to present a challenge to students and to give them experience in problem solving as they develop more proficiency in the metals area. These projects lend themselves to many different designs and construction methods. You may want to change the size of some of these plans to fit your own needs. For example, the shelf may be too large, or you might want to hang your house number sign on a post, which would require a different bracket.

HOUSE NUMBER SIGN

This house number sign, Fig. 12-1, is a good beginning project. Its construction involves some important hand tool operations which can be applied to numerous other projects. You may want to change the design of the scroll work or the shape of the plate which holds the numbers. Patterns for the numbers can be made so they can be cast in the foundry or they may be cut from aluminum or brass sheet stock.

MATERIAL:

Standard:	1 pc. band iron 1/8 x 1/2 x 37 in.
Scrolls:	1 pc. band iron 1/8 x 1/2 x 21 in.
Plate:	1 pc. black iron 22 ga. 5 x 14 in.
Hooks:	1 pc. mild steel 1/8 in. dia. x 7 in.
Rivets:	4 black iron 1/8 x 1/2 in. round head.
Numbers:	Aluminum or brass—cast in foundry, cut from sheet stock, or purchase.

Fig. 12-1. House number sign.

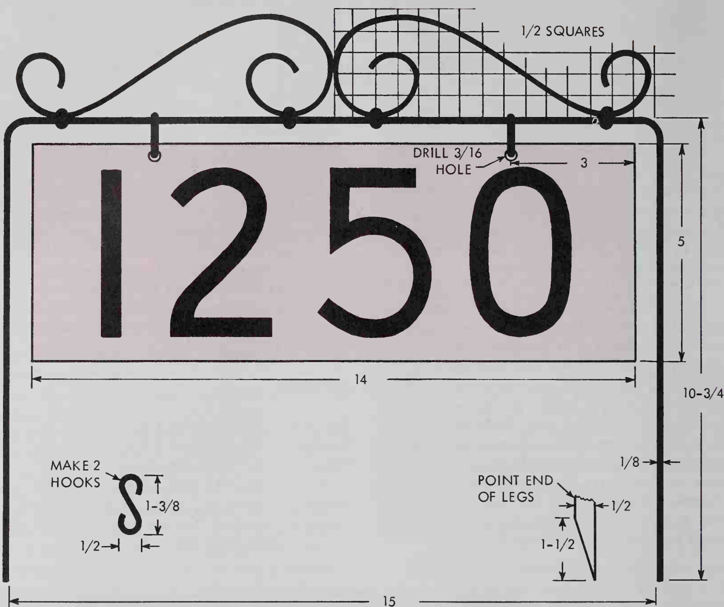


Fig. 12-2. House number sign, working drawing.

PROCEDURE:

1. Draw a full-size pattern of the scroll on squared paper. See Fig. 12-2.
2. Figure the amount of material needed for the scrolls and cut to correct length.
3. Square the ends of the metal and remove burrs.
4. Form the scrolls.
5. Cut material to length for the standard.
6. Lay out pointed ends on both legs of the standard.
7. Cut the ends to shape and file the edges.
8. Mark off bends on material for standard.
9. Make 90-deg. bends with a small radius as shown on drawing.
10. Lay out number plate on 22 ga. black iron.
11. Cut number plate to size, and file all edges.
12. Lay out location of holes.
13. Center punch and drill holes.
14. Cut out stock for hooks.
15. Form hooks.
16. Locate rivet holes on scrolls and center punch.
17. Drill 1/8 in. dia. holes in scrolls.
18. Locate rivet holes on the standard and center punch.
19. Drill 1/8 in. dia. holes in the standard.
20. Rivet the scrolls to the standard.
21. Draw full-size pattern of figures on metal. (If you cast your figures in the foundry, skip procedure 21 and 22).
22. Cut out figures and polish.
23. Locate rivet holes on figures.
24. Center punch and drill holes in figures for rivets.
25. Rivet figures to both sides of the plate.
26. Paint as desired.
27. Insert hooks in the standard and attach the number plate.

WALL PLANT HOLDER

This wall plant holder, Fig. 12-3, is an attractive planter for displaying trailing vines and green plants. Flattened expanded metal or perforated metal can be used for the back, Fig. 12-4. All pieces are joined with solder. While soft solder, properly applied will serve satisfactorily, hard soldering will make the project stronger. If you have a spot welder in your shop, the expanded metal can be joined to the wire frame with it very easily. All of the metal parts must be cleaned thoroughly before applying the finish. This project is very attractive when given a satin black finish.

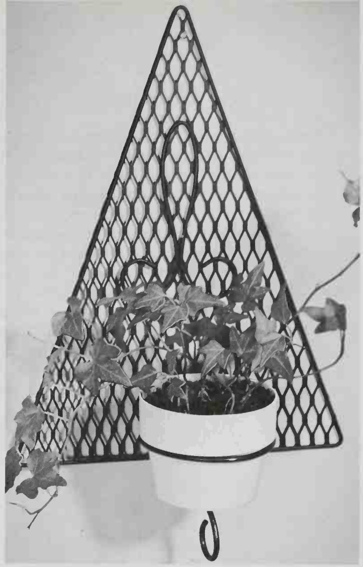
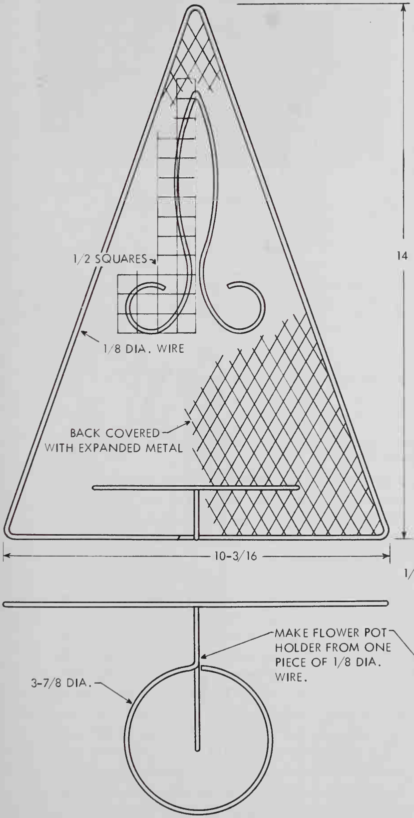


Fig. 12-3. Wall plant holder.



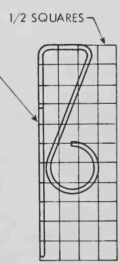


Fig. 12-4. Wall plant holder, working drawing.

PICTURE EASEL

A picture easel is a project that can be used to add a decorative touch to any room. The easel may be constructed of band iron or strips of 16 gage brass. Follow pattern, Fig. 12-6. The trough that holds the picture can be made from 22 gage sheet iron or 20 gage sheet brass. Note that a chain is used to keep the easel tripod leg from opening too far. The metal strips can be decorated by peening. All parts should be fastened together by soldering (hard solder preferred). A unique and attractive finish can be obtained on band iron by painting the project flat black, then highlighting all of the parts with gold Rub'N Buff. If you use brass to construct your project, it is suggested that you polish the brass pieces and finish with metal lacquer, Fig. 12-5.

Fig. 12-5. Picture easel.

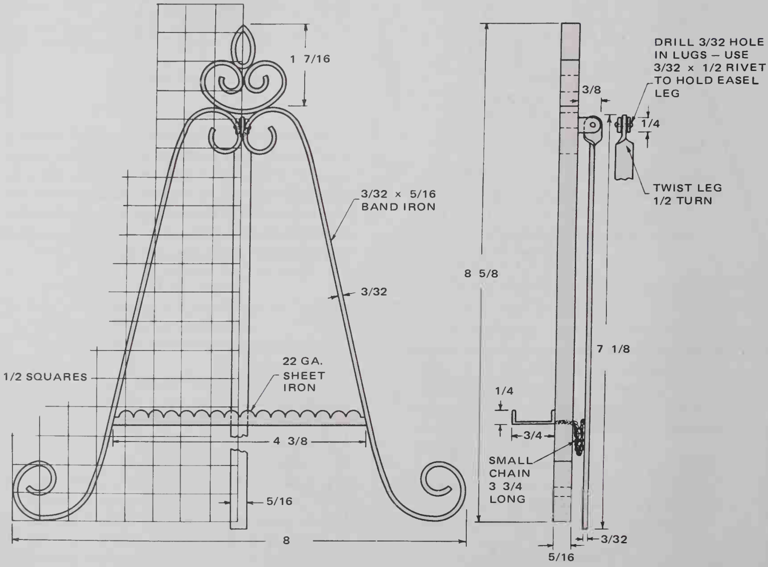


Fig. 12-6. Picture easel, working drawing.

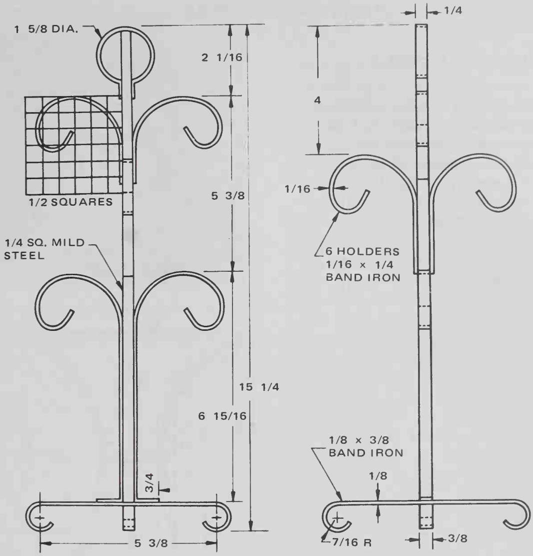


Fig. 12-7. Mug holder, working drawing.

MUG HOLDER

This project provides an attractive way to hang up your coffee, tea, or hot chocolate mug. The first step of procedure is to make a full size drawing of the cup hangers by enlarging the squares as indicated on the working drawing, Fig. 12-7. You will notice that the four cup hangers located at the upper portion of the stand have a stem 1 3/8 inches long which is fastened to the stand. The two lower hangers require a stem 6 inches long. A 3/4 in. section is bent 90 degrees to the base—this portion provides support for the stand. After all of the pieces have been cut to size and properly formed, you are ready for assembly. The parts of your mug holder may be spot welded together or you might choose to use rivets for this operation. After the holder has been assembled, you will need to adjust the base so all four ends of the scroll touch the surface of your work bench and do not allow the holder to rock. The finish can be a bright enamel color which will match the decor of the room where the holder will be used. See Fig. 12-8.

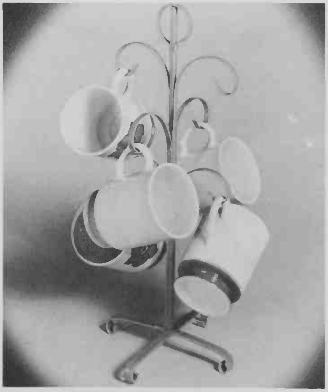


Fig. 12-8. Mug holder.

WROUGHT IRON TABLE

Here is a project that you will find interesting to construct and a very useful piece of furniture. Construction is simple and it provides you with an opportunity to do some welding. It will be necessary for you to draw a full-size pattern, Fig. 12-10, of the leg by enlarging the squares to one inch. After you have formed the legs to the shape of your pattern, form the 14 in. dia. and the 4 in. dia. rings. The top end of the legs provide a support for the plastic disc top. Weld the legs to the top ring 3/16 in. from the top. This will allow the 3/16 in. plastic disc to rest on the legs and be flush with the top edge of the ring. You may want to design a jig to hold the legs in place while welding them to the two rings. The feet can be made out of brass or you might choose to use rubber tips that are commonly used on wrought iron furniture. The finish for this project should include a metal primer for the undercoat and metal enamel of the desired color for the finish coat. See Fig. 12-9.

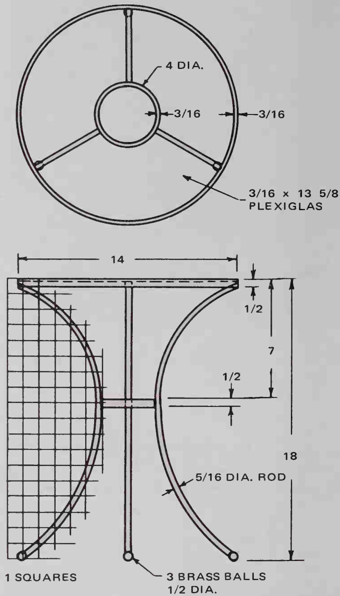


Fig. 12-10. Wrought iron table, working drawing.

Fig. 12-9. Wrought iron table.

OWL TRIVET

This is a handy project that will keep the hot dishes from damaging the finish on a table or counter top. You will want to select a piece of heavy gage shee metal such as .080 in. thick aluminum or 12 gage brass. Make a full-size pattern on a piece of tracing paper and glue it to the piece of metal selected with rubber cement. Drill 1/8 in. holes in each of the areas to be cut out. A jeweler's saw or a scroll saw equipped with a metal cutting blade may be used to cut out the owl. Attach cork discs to the bottom of the owl as indicated on the drawing, Fig. 12-12. Also, see Fig. 12-11.

Fig. 12-11. Owl trivet.

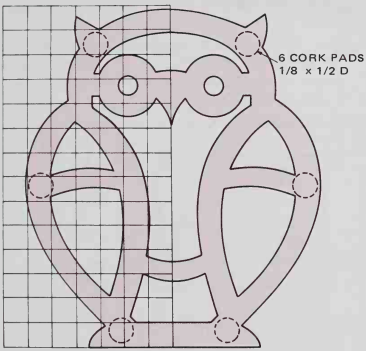


Fig. 12-12. Owl trivet, working drawing.

METAL SWTICH PLATE

This attractive plate protects the wall finish and helps keep the wall clean around an electric switch. You may want to draw your own design. The dimensions given for the screw holes and the cut outs for the switch lever are standard and will fit all junction boxes. A single switch plate can be made using these dimensions. Remember that only two screw holes and one switch lever slot will be needed. The drawing, Fig. 12-14, indicates that the plate is raised 3/16 in. at the center. This allows the plate to fit flush against the wall. You will note that the screw holes are formed (countersunk) to receive screws with oval heads. The surface of the plate may be decorated with different shaped peen marks. 24 oz. copper or 20 ga. brass makes a very attractive plate. Finish the plate with metal lacquer. See Fig. 12-13.

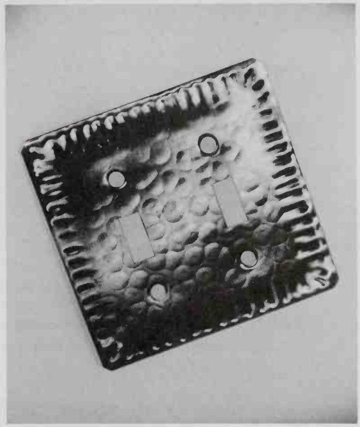


Fig. 12-13. Metal switch plate.

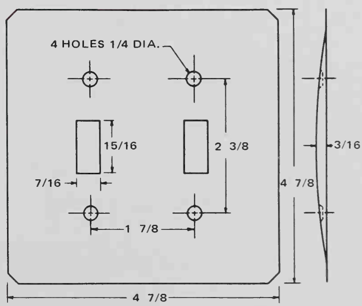


Fig. 12-14. Metal switch plate, working drawing.

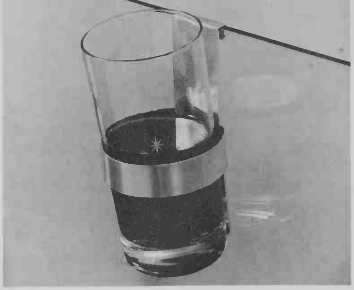


Fig. 12-15. Beverage glass holder.

BEVERAGE GLASS HOLDER

This project comes in handy at the drive-in or when you are traveling. The holder is made out of .032 in. half-hard sheet aluminum. The ends of the band lap over each other on the rear side of the back piece that hooks onto the car window glass, Fig. 12-15. Two rivets, as indicated in the drawing, Fig. 12-16, provide a good method for fastening the band to the back piece. A satin finish is recommended. You may want to change the dimensions given in the drawing to fit beverage glasses which are larger or smaller.

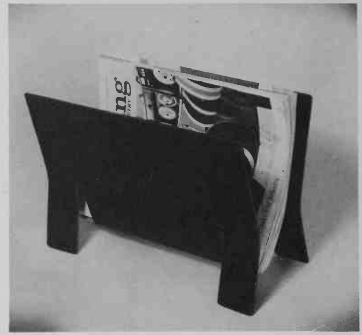


Fig. 12-17. Magazine rack.

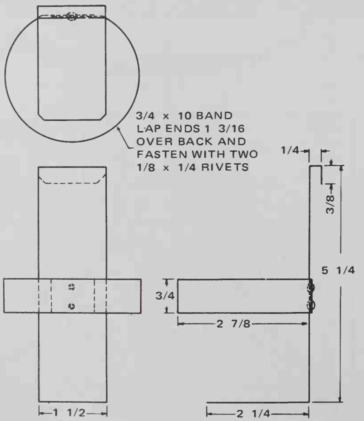


Fig. 12-16. Beverage glass holder, working drawing.

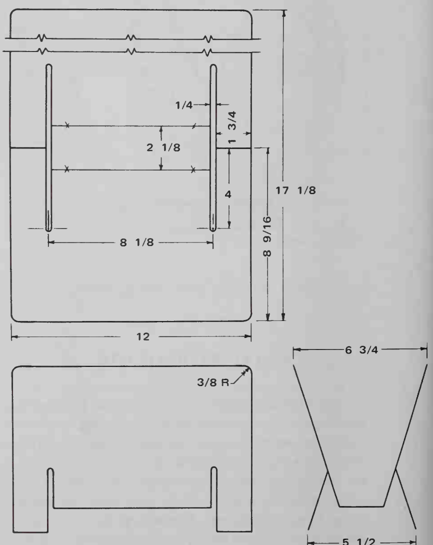


Fig. 12-18. Magazine rack, working drawing.

RACK FOR MAGAZINES

This is a unique project made from one piece of sheet metal. One-half hard aluminum .064 in. thick works real well, although sheet iron is less expensive and works satisfactorily. Lay out the pattern on the selected metal sheet and cut the stock to size as indicated in the drawing, Fig. 12-18. Drill the ends of the two slots with a 1/4 in. drill. Cut the part which forms the legs and finish cutting out the slots. All of the corners should be rounded with a file. Carefully bend the metal to form the rack as shown on the drawing. Select a finish that fits the decor of the room where you will use the rack. See Fig. 12-17.

CHISEL AND PUNCH SET

A set of chisels and punches added to your tool kit will come in handy for many jobs. Use square tool steel to make these tools. The punches are turned to shape on a lathe. The chisels are forged to shape. Using these designs you can make various sizes of chisels and punches for your set. Round off the striking end in a lathe as indicated in the drawing, Fig. 12-20. After you have shaped your chisels and punches they are ready to be heat treated. It is suggested that you polish the rounded ends and the work end of these tools. The center punch point and the cutting edge of the chisel are ground to the proper shape on a tool grinder. See Fig. 12-19.

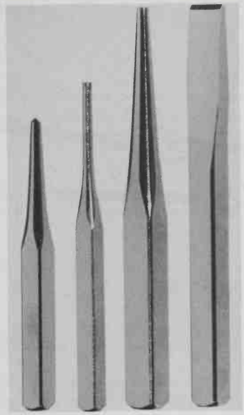


Fig. 12-19. Chisel and punch set.

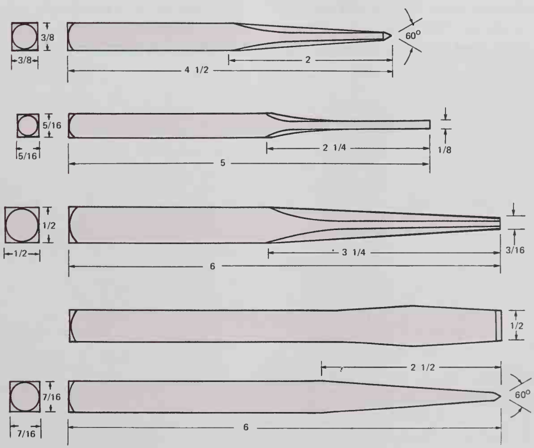


Fig. 12-20. Chisel and punch set, working drawing.

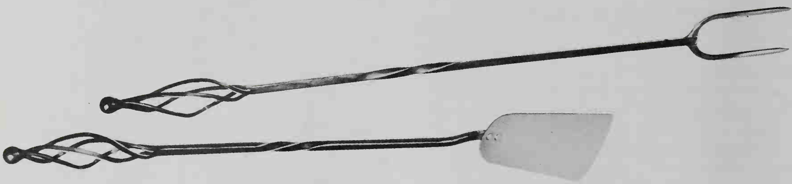


Fig. 12-21. Barbecue tools.

BARBECUE TOOLS

The barbecue tools shown in Fig. 12-21 have very unique spiral handles which are sure to make them conversation pieces. They look difficult to make but the spiral handle is really very simple to form. Slot one end of the handle as shown in Fig. 12-22. Braze or weld the ends of the four prongs together. If you do not have equipment to braze or weld the pieces, the slots can be made by drilling 1/16 inch holes along the slots until you can insert a hacksaw blade to finish the cuts. Start drilling the holes 1/4 in. from the end of the handle. The spirals are formed by clamping the end of the metal in a vise and twisting the metal with a wrench. The jaws of the wrench should grip the metal close to the end of the slots. As the metal is twisted it will become shorter and cause the four prongs to spread and twist. If the prongs do not spread evenly, shape them with a pair of pliers. The twist in the solid part of the handles is formed by clamping one end of the section to be twisted close to the edge of the vise jaws. Place the jaws of a wrench at the other end of the section and twist. The spatula and fork can be made of stainless steel, hard tempered aluminum, or sheet steel. The fork and spatula should be polished. The handles can be finished by coating them with oil and heating the metal until the oil is burned off. Then the surface of the metal should be polished, using a soft clean rag to produce a smooth satin sheen.

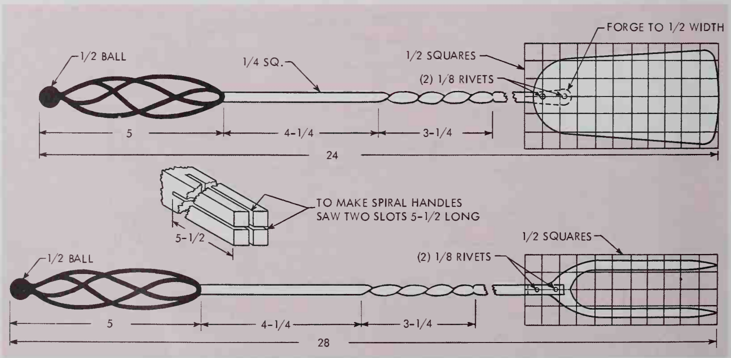


Fig. 12-22. Barbecue tools, working drawing.

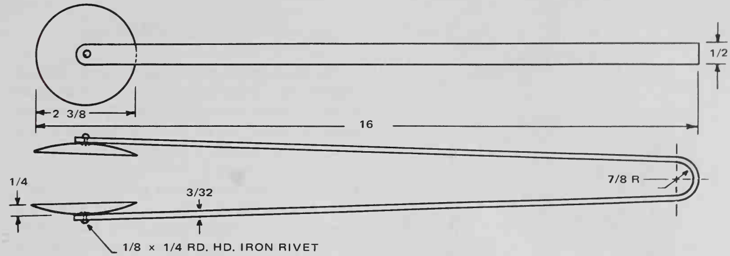


Fig. 12-23. Charcoal tongs, working drawing.

CHARCOAL TONGS

These tongs are a must if you like to barbecue with charcoal. They are simple to construct, Fig. 12-23. Use cold rolled steel for the handle since this kind of metal has just the right amount of hardness to create the spring-back needed to open the discs when releasing the coals. The two discs can be made from 24 gage sheet iron. Hammer the discs to shape over a stake or a hard wood form that has been hollowed out. The discs can be riveted or spot welded to the handle. A heat resistant black paint is recommended to insure a satisfactory bond between the metal and the paint. See Fig. 12-24.

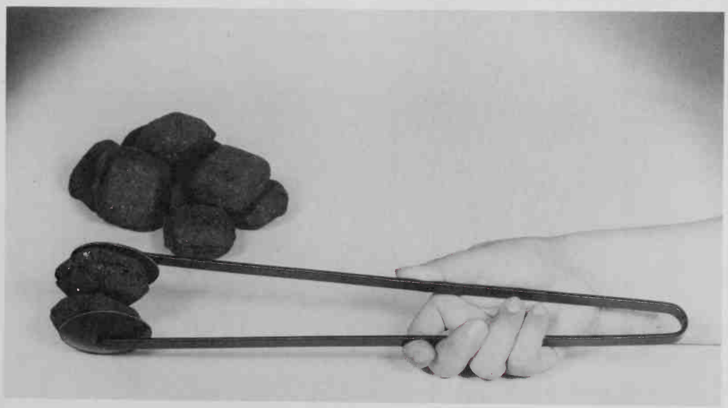


Fig. 12-24. Charcoal tongs.

Fig. 12-25. Door knocker.

DOOR KNOCKER

The classic grace of Colonial design in the door knocker, Fig. 12-25, will add distinction to any door. It may be cast in aluminum or brass. The pattern can either be carved out of wood or modeled in clay which is used to make a plaster of Paris mold. The plaster of Paris mold is then used to cast a metal pattern that can be used for green sand foundry work. A hole is drilled in the back side of the knocker plate at the top and at the bottom for a 10-24 machine screw to attach the knocker to a door. The striker is fastened to the plate with two rivets, Fig. 12-26. If aluminum is used, a satin finish is very attractive. Brass is generally given a buffed finish, and should be lacquered to prevent tarnishing.

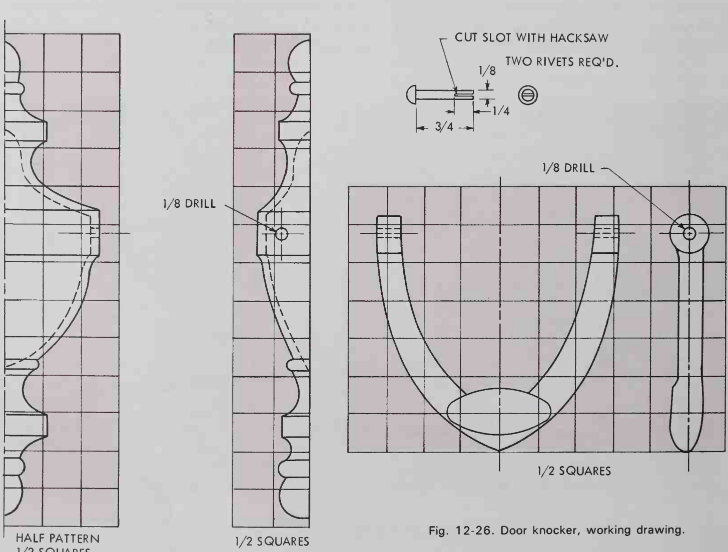


Fig. 12-26. Door knocker, working drawing.

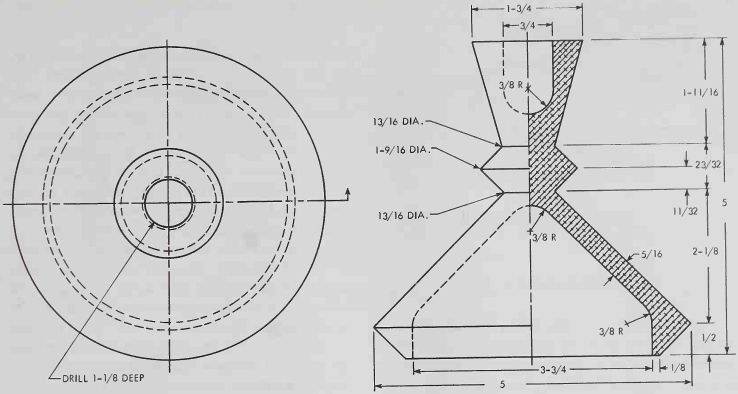


Fig. 12-27. Candle holder, working drawing.

CANDLE HOLDER

The light reflections given off of the flat tapered surfaces of the candle holder, Fig. 12-28, makes it a most beautiful piece that will blend with modern or traditional trends. This project requires two patterns and a core mold. A one-piece pattern is made for the base, and a split-pattern is used for the stem and holder. A shank is cast on each part to provide a means for chucking. The hole for the candle is formed with a core. The project is attractive cast in either aluminum or brass. Turn the holder to shape in the lathe and drill and tap the stem for a 10-24 x 1 in. machine screw. Turn the base to shape, and drill a clearance hole through the center for a 10-24 machine screw which is used to join the holder and stem to the base, Fig. 12-27. A highly buffed polish brings out the beauty in this project.

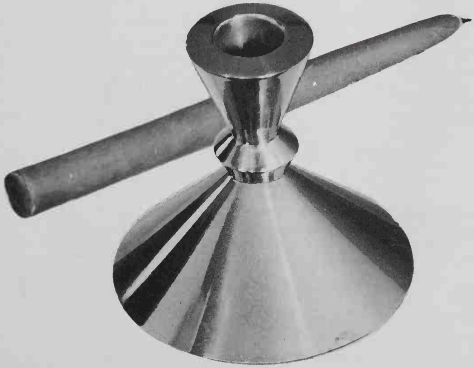


Fig. 12-28. Candle holder.

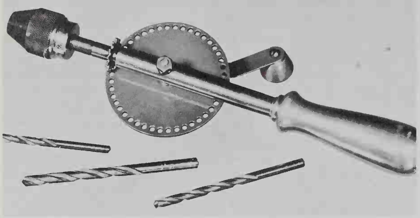
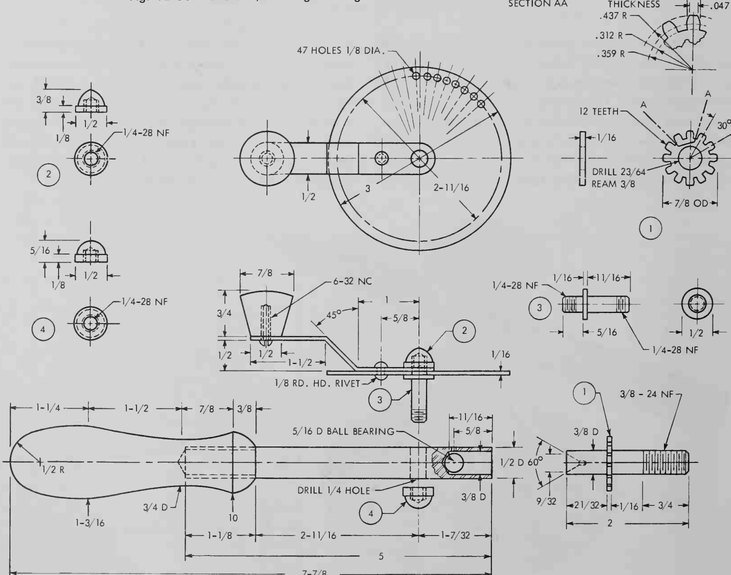


Fig. 12-29. Hand drill.

HAND DRILL

This hand drill is an interesting and challenging project. All of the parts can be made of mild steel except the handle which should be made of aluminum or wood to give the tool better balance. A 3-jaw, 1/4 in. chuck can be purchased. The chuck shaft gear and the drive wheel are the pieces which are most difficult to make. The drive wheel must be accurately laid out and drilled in order to work properly. The teeth on the gear are made by drilling 3/64 in. holes between them, close to the root circle, and then cutting out surplus metal left between the teeth with a hacksaw. Finish the gear by filing to the layout lines. A jig can be developed that can be used to drill evenly spaced holes in the drive wheel. See if you can design a jig for this operation. After all of the parts have been made, attach the drive wheel to the body of the drill. Insert the ball bearing and chuck shaft in the end of the body. Hold the chuck shaft tightly against the ball bearing, and adjust the gear on the shaft until the teeth match perfectly with the holes in the drive wheel. The chuck shaft gear can be attached by brazing. Or, you can use a 1/16 in. key between the shaft and the gear, and hard solder the pieces together. After gear has been joined to shaft, assemble the drill, and test it. File off high spots on teeth of the gear that do not mesh, Figs. 12-29 and 12-30.

Fig. 12-30. Hand drill, working drawing.



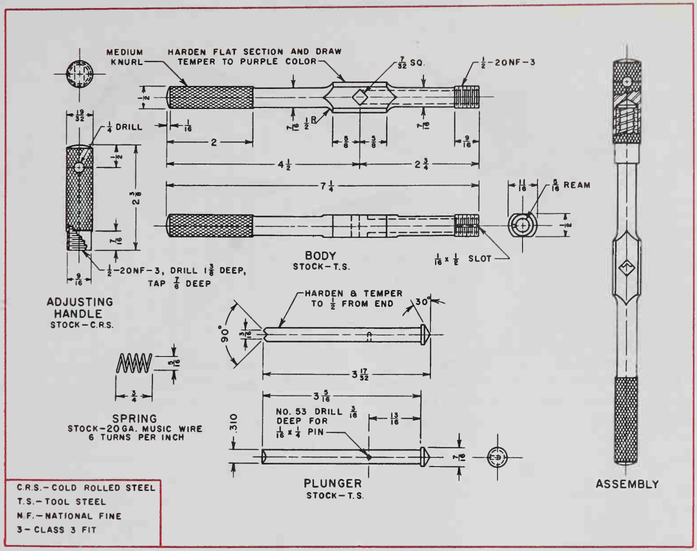


Fig. 12-31. Tap wrench, working drawing.

TAP WRENCH

The tap wrench, Fig. 12-32, is another tool that will come in handy and one that should be added to your tool kit. Follow the drawing, Fig. 12-31, to construct this project. All of the parts are made in the lathe, even the winding of the spring. The 9/16 in. hole in the end of the adjusting handle should be drilled and tapped in the lathe. The threads on the right end of the body can be threaded in the lathe, or with a threading die. If a threading die is used, great care must be taken to start the threads straight. The square hole in the body is made by drilling first with a 7/32 in. drill, then filing the hole square with a square file. The wrench parts which are made from cold rolled steel should be casehardened.

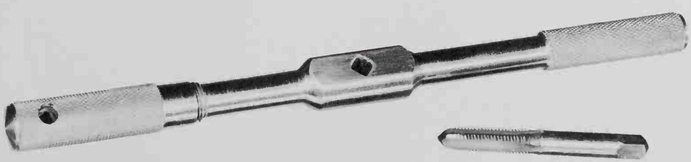


Fig. 12-32. Tap wrench.

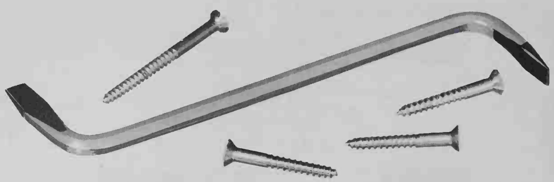


Fig. 12-33. Offset screwdriver.

OFFSET SCREWDRIVER

The offset screwdriver, Fig. 12-33, will come in handy for those hard-to-get-to places. You will want one in your tool kit. This tool is made of water hardened tool steel. Two or three different sizes of metal can be used to make a set. Forge the points of the blades to shape and anneal the metal. Then bend the offsets, harden and temper the points, as shown in Fig. 12-34.

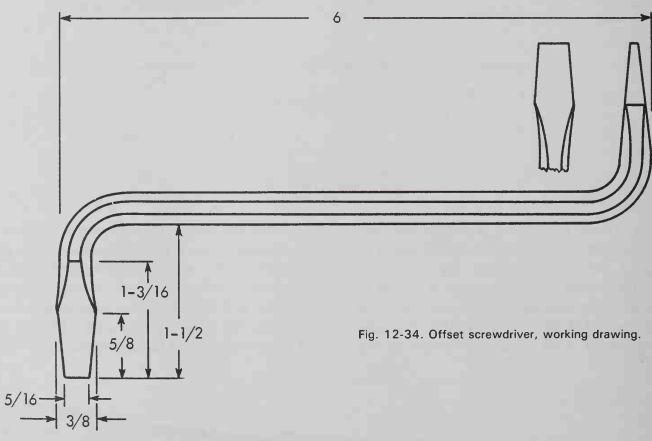
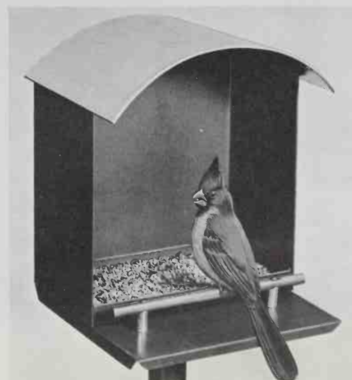


Fig. 12-34. Offset screwdriver, working drawing.

BIRD FEEDER

The bird feeder, Fig. 12-35, will provide you with many interesting hours watching birds that visit the feeder. The house can be made of 24 ga. sheet metal. The front of the roof has a wired edge—use No. 16 wire, Fig. 12-36. The perch is made of 1/2 O.D. aluminum tubing. Fasten the perch to the floor of the feeder with either round-head machine screws, or rivets. The roof and the floor of the feeder can be joined to the sides by soldering, riveting, or spot welding. The pipe which can be used to attach the feeder to a pole is optional and depends on how you plan to hang your bird feeder. The finish should be a dark shade of green or brown since birds tend to be cautious of bright colors.

Fig. 12-35. Bird feeder.



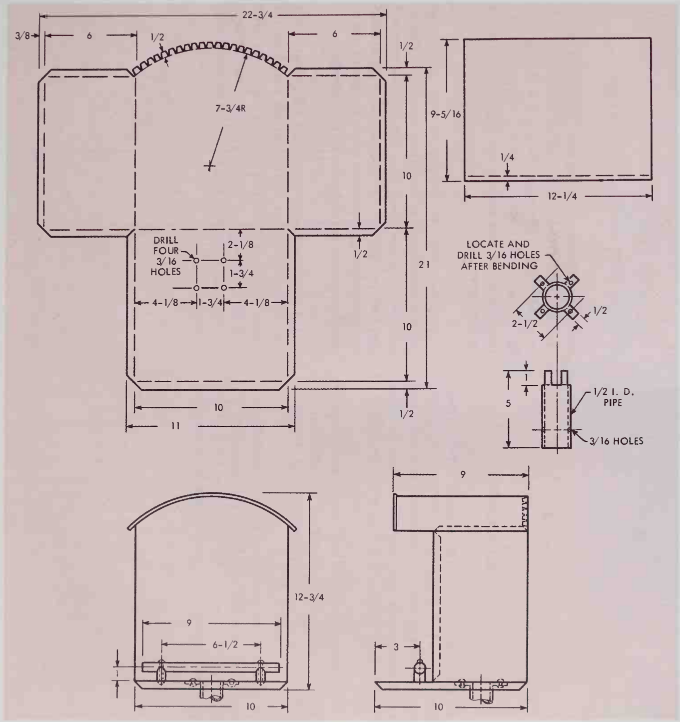


Fig. 12-36. Bird feeder, working drawing.

Fig. 12-37. Clock case.

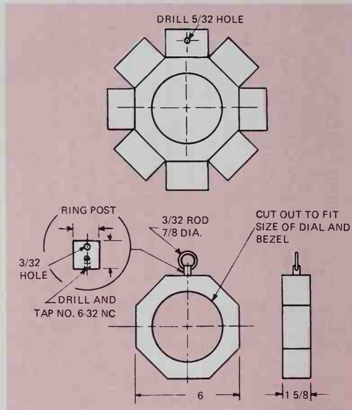


Fig. 12-38. Clock case, working drawings.

CLOCK CASE

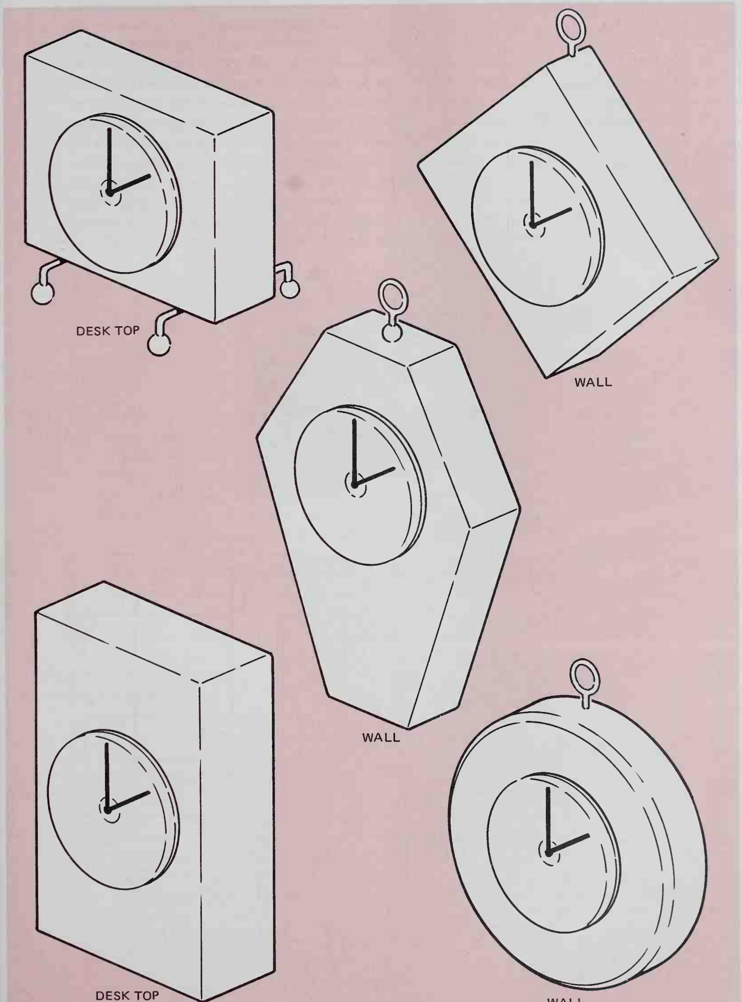
A metal clock case can be made for electric, key-wound or battery movements. These movements are available from several companies that sell clock kits and accessories. You may have a clock at home that could be mounted in a case that you design.

The octagon case, Fig. 12-37, was constructed out of 26 ga. steel sheet. Brass, copper or aluminum may be used. Refer to working drawings, Fig. 12-38.

Lay out the pattern on the metal you have chosen. The size of your dial and bezel will determine the diameter of the hole to be cut in the front of the case. After cutting the metal to shape, bend the eight tabs to form the sides of the case. Solder the joints. The ring can be made from 3/32 in. dia. welding rod. The ring post can be made from a 3/8 in. dia. rod. Locate and drill a hole in the top for a No. 6-32 machine screw that fastens the ring post to the top of the case.

You may want to design your own clock case using a combination of metal and decorative attachments such as overlays or feet. The sketches provided may help you with your original design. Keep in mind the metalworking processes you will need to use in carrying out the construction of your design.

The finish will depend on the kind of metal you use. If you use sheet steel, coat the metal with a primer and then apply the color of paint you have chosen. For copper or brass you can use either a brushed or buffed finish and then coat the metal with lacquer.



ALTERNATE CLOCK FRAMES

TOOL PANEL ORGANIZER

The tool panel organizer, Fig. 12-39, provides a shelf to hold small tools, glue and miscellaneous items. The drawers are handy for nails, wood screws or machine screws. Construct the shelf, drawers and drawer pulls out of 26 ga. sheet steel. The six drawer glides are made from 28 ga. sheet steel. Lay out the shelf pattern on the metal and cut to shape. Locate the mounting holes and drill them. Fold lines are indicated on the drawing. The hem on the front of the shelf should be bent to the underside of the shelf surface. After all of the bends have been made to form the shelf, solder the tabs on the sides to the back. Lay out the drawers on the metal and cut them out. Make bends to form the drawers. The 3/16 in. lips on the drawer sides are bent 90 degrees to the sides to form the drawer slides. Solder the tabs to the sides. Cut out drawer pulls and bend them to shape. Solder the drawer pulls to the drawers. Cut out the six drawer glides and bend them to form a channel shape for the drawer lips to slide in. Mark the location for the drawer glides on the underneath side of the shelf. Solder the drawer glides to the bottom of the shelf. Finish as desired. See Fig. 12-40.

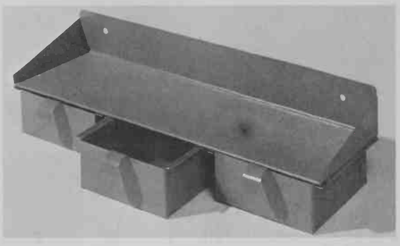


Fig. 12-39. Tool panel organizer.

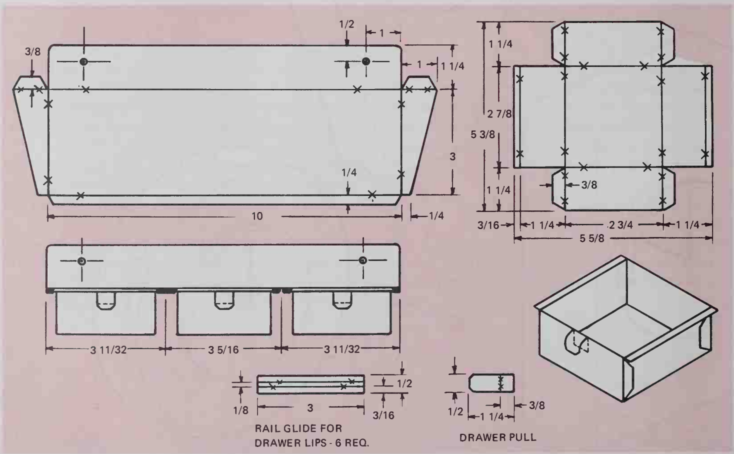
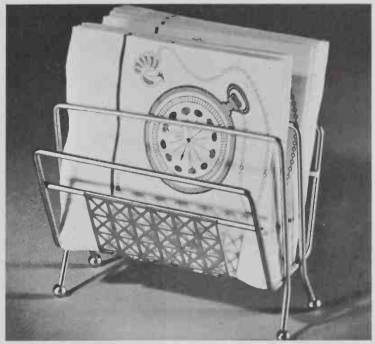


Fig. 12-40. Working drawings for tool panel organizer.

For these projects, only over-all dimensions and material suggestions have been included. Dimensions for individual parts have been omitted, so the development of the plans may be used to teach designing and problem solving.

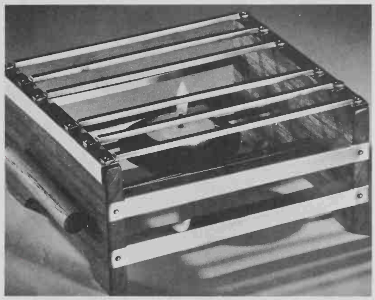
METAL NAPKIN RACK

SIZE: 3 1/2 wide x 4 1/2 high x 5 1/4 long.
MATERIAL: Frame – 1/8 wire.
Holder – 24 ga. perforated steel.
Feet – 5/16 steel balls, or No. 13 1/8 dia. rubber tips.



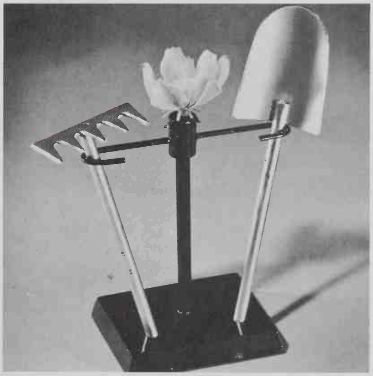
DISH WARMER – Uses Candle For Fuel

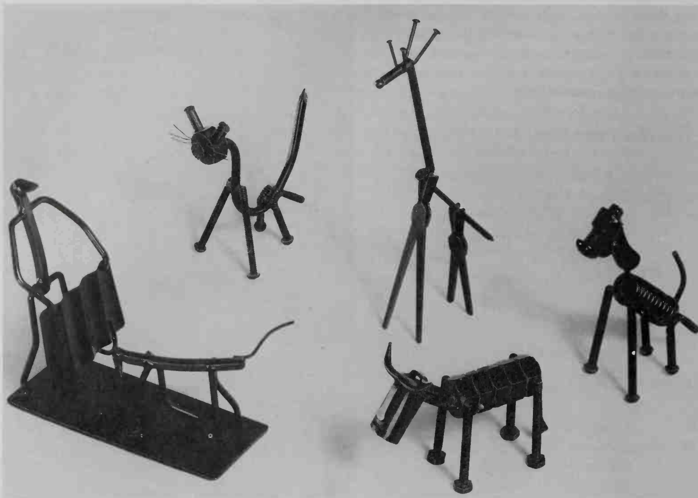
SIZE: 3 high x 5 1/4 wide x 6 long.
MATERIAL: Ends - wood or 24 oz. copper.
Handles – 1/2 dia. maple dowel.
Slides – 16 oz. copper.
Grill – 1/8 square copper bars.
Candle Holder – 20 ga. sheet iron.
Candle Holder Support – 1/8 dia. wire.
Rivets – 1/4 x 3/32 dia. copper or 1/2 No. 16 Round head Escutcheon Pins if wood ends are used.



TOOLS FOR POTTED PLANT GARDENERS

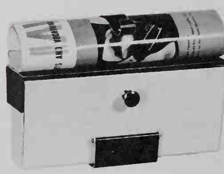
SIZE: Holder – 2 1/2 x 3 x 6 1/8.
Spade – 6 1/8 long, 1 5/8 wide.
Rake – 4 5/8 long x 2 wide.
MATERIAL: Tool Holder –
Base – 1/2 x 2 1/2 x 3 cast aluminum.
Standard – 5/16 dia. steel rod.
Standard Knob - 1/2 dia. steel rod.
Plastic Flower – Small.
Tool Holder – 3/32 dia. wire.
Spade –
Handle – 1/4 dia. brass rod.
Blade – .040 thick sheet brass.
Rake –
Handle – 1/4 dia. brass rod.
Teeth – .064 thick sheet brass.





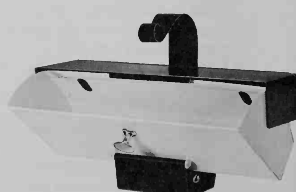
HARDWARE SCULPTURE

The hardware sculptures are fun to create. They are constructed from springs, nuts, bolts, wing nuts, nails, tubing, sheet metal, etc. – pieces from the metal scrap box. Keep sizes of materials in proper proportion.

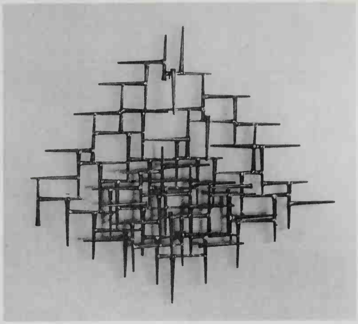


MAILBOX

SIZE: 5 deep x 6 high x 14 3/4 long.
MATERIAL: Body – 22 ga. sheet metal
Lid and hinge – 20 ga. sheet metal.
Magazine holder – 26 ga. spring steel.
Hinge pin – 3/32 wire.



WALL SCULPTURE



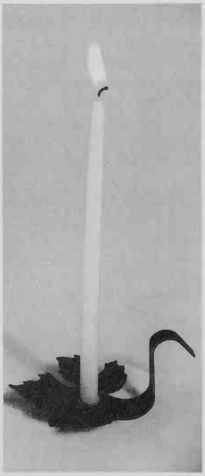
SIZE: Approximately 22 in. x 22 in.
MATERIAL: Old fashion iron nails 3 1/2 in. long.
NOTE: Weld the nails together to create the design. Other kinds of metal rods and strips of sheet metal can be used to form interesting sculptures.

CANDLE HOLDERS

Wrought Iron Candle Holder

SIZE: 2 3/8 in. dia. base by 2 in. high.
MATERIAL: Base and stem — 1/4 in. sq. x 9 in. long mild steel. Candle holder disc — 18 ga. x 2 in. dia. sheet steel.
Pin (center of disc) — 1/16 in. dia. x 1/2 in. long.
NOTE: Twist the square rod and bend to form base and stem. Cut out 2 in. disc and cup it to form a dish 3/16 in. deep. File pin to a sharp point so it can be stuck into the center of the candle easily. Braze or hard solder the pin and disc to the top of the stem.

Leaf Candle Holder



SIZE: 3 1/4 in. wide x 4 3/4 in. long.
MATERIAL: Handle and base — 18 ga. sheet steel 1 1/8 in. wide x 5 3/4 in. long.
Leaf — 28 ga. sheet steel 3 1/4 in. wide x 3 3/8 in. long.
Pin — 1/8 in. dia. x 3/4 in. long mild steel.
NOTE: Make a maple leaf pattern and transfer to sheet steel. Cut out leaf and cup it to a dish shape. Cut out metal for handle and base (taper piece from 1 1/8 in. wide at one end to 5/16 in. wide at the other end) and bend it to form the base and handle. Taper the candle holder pin to a sharp point at one end. Drill a 1/8 in. hole through the center of the leaf. Press the pin into the hole in the leaf. Position the leaf on the base and solder the leaf to the base. Finish with semi-gloss black enamel.

CONVERSION TABLE
METRIC TO ENGLISH

WHEN YOU KNOW	MULTIPLY BY: (* = Exact) VERY ACCURATE	APPROXIMATE	TO FIND
LENGTH			
millimetres	0.0393701	0.04	inches
centimetres	0.3937008	0.4	inches
metres	3.280840	3.3	feet
metres	1.093613	1.1	yards
kilometres	0.621371	0.6	miles
WEIGHT			
grains	0.00228571	0.0023	ounces
grams	0.03527396	0.035	ounces
kilograms	2.204623	2.2	pounds
tonnes	1.1023113	1.1	short tons
VOLUME			
millilitres		0.2	teaspoons
millilitres	0.06667	0.067	tablespoons
millilitres	0.03381402	0.03	fluid ounces
litres	61.02374	61.024	cubic inches
litres	2.113376	2.1	pints
litres	1.056688	1.06	quarts
litres	0.26417205	0.26	gallons
litres	0.03531467	0.035	cubic feet
cubic metres	61023.74	61023.7	cubic inches
cubic metres	35.31467	35.0	cubic feet
cubic metres	1.3079506	1.3	cubic yards
cubic metres	264.17205	264.0	gallons
AREA			
square centimetres	0.1550003	0.16	square inches
square centimetres	0.00107639	0.001	square feet
square metres	10.76391	10.8	square feet
square metres	1.195990	1.2	square yards
square kilometres		0.4	square miles
hectares	2.471054	2.5	acres
TEMPERATURE			
Celsius	*9/5 (then add 32)		Fahrenheit

CONVERSION TABLE
ENGLISH TO METRIC

WHEN YOU KNOW	MULTIPLY BY: (* = Exact) VERY ACCURATE	APPROXIMATE	TO FIND
LENGTH			
inches	* 25.4		millimetres
inches	* 2.54		centimetres
feet	* 0.3048		metres
feet	* 30.48		centimetres
yards	* 0.9144	0.9	metres
miles	* 1.609344	1.6	kilometres
WEIGHT			
grains	15.43236	15.4	grams
ounces	* 28.349523125	28.0	grams
ounces	* 0.028349523125	.028	kilograms
pounds	* 0.45359237	0.45	kilograms
short ton	* 0.90718474	0.9	tonnes
VOLUME			
teaspoons		5.0	millilitres
tablespoons		15.0	millilitres
fluid ounces	29.57353	30.0	millilitres
cups		0.24	litres
pints	* 0.473176473	0.47	litres
quarts	* 0.946352946	0.95	litres
gallons	* 3.785411784	3.8	litres
cubic inches	* 0.016387064	0.02	litres
cubic feet	* 0.028316846592	0.03	cubic metres
cubic yards	* 0.764554857984	0.76	cubic metres
AREA			
square inches	* 6.4516	6.5	square centimetres
square feet	* 0.09290304	0.09	square metres
square yards	* 0.83612736	0.8	square metres
square miles		2.6	square kilometres
acres	* 0.40468564224	0.4	hectares
TEMPERATURE			
Fahrenheit	* 5/9 (after subtracting 32)		Celsius

GLOSSARY

ABRASIVE: Material that is able to abrade (cut) material softer than itself.

ACETYLENE: A gas composed of two parts carbon and two parts hydrogen. When burned in the presence of oxygen, it produces a high flame temperature.

ALLOY: A combination of two or more metals that are melted and mixed together in certain proportions. For example, brass is a metal alloy produced by mixing copper and zinc.

ALUMINUM: A bright silver nonferrous metal which is light and strong.

ALUMINUM OXIDE: Artificial abrasive made from bauxite ore.

AMERICAN NATIONAL THREAD SYSTEM: Standard system of sizes and pitches of threads formerly used by all U.S. manufacturers. Now being phased out by some companies which are changing to metric standards.

ANNEALING: Process of softening steel to make it easier to machine, cut, stamp or shape. Another purpose is to relieve stress and hardness resulting from cold working.

ANVIL: Heavy block of steel or iron used as a work surface in forging and blacksmithing.

ARC WELDING: Fusing metals by means of an electrode and an electric current. The electrode is held near the workpiece so that the electric current jumps the gap creating high temperature in a small area.

AVIATION SNIPS: Tin snips with compound handles designed for cutting compound curves and intricate designs.

BALANCE: Principle of design in which an object's parts seem to be of equal weight. There are two types: formal and informal.

BALL PEEN HAMMER: Forging hammer with a rounded, ball shaped peen.

BAR FOLDER: Machine for folding sheet metal with straight bends. Consists of two bars—one stationary and one moved by a handle. Gages and stops control angles and depths.

BEAD: Ridge of deposited and melted metal formed at a welded joint.

BERYLLIUM: Space age metal which is lightweight and maintains good properties even at very high temperatures. It is useful in nuclear reactors and spacecraft.

BOX AND PAN BRAKE: Sheet metal bending machine for bending metal boxes and pans.

BRASS: An alloy of copper and zinc having a distinctive gold color. It is easy to hammer, saw and file.

BRAZING: A process for joining metals similar to soldering. It uses spelter (a compound of copper and zinc) instead of solder as the filler metal.

BUFFING: Polishing operation performed on metal using a cloth buffing wheel that has been filled with a mild abrasive compound.

BUTT JOINT: Welding two pieces of metal together edge-to-edge with no overlapping.

CARBON: Element combined with iron to make steel. In solid form it is used as an electrode for arc welding.

CASE HARDENING: Process of hardening outer surface of metal harder than the inside. Performed on parts such as gears, screws, hand tools and roller bearings which need a hard-wearing surface.

CASTINGS: Articles produced by founding (pouring hot, liquid metal into a mold).

CENTER PUNCH: Punch with one end ground to a 90 degree conical point. Used to enlarge prick punch marks.

CHIPPING HAMMER: Special hammer with point on one side of head and straight peen on other side for removing slag from weld bead. A variation has a straight peen on one side and a brush on the other side.

CHISEL: Wedge-shaped tool used to shear, cut and chip metal. Various types include flat cold chisel, diamond point chisel, cap chisel and round nose chisel.

CHUCK: Tool for holding work or cutting tools on a machine tool.

COLUMBIUM: Chemical element under experiment in development of new metals for nuclear reactors. It has a melting point of about 4380 deg. F. and is resistant to radiation damage.

COLOR: An element of design which designers take into consideration. Since metals have colors of their own, it is up to the designer to use the color as a part of the overall appearance.

COMBINATION SQUARE SET: A set of tools with four parts consisting of a blade, a 45-degree head, a 90-degree head, a protractor head and a center head. It is used to check squareness, 45 degree angles, as a depth gauge or for finding the centers of circles. The protractor head measures angles up to 180 degrees. The blade is used as a marking gauge and as a depth gauge.

COPE: The top section of a flask used in casting.

COPPER: Rich, reddish brown nonferrous metal. It is easy to form and solder.

CORE: A shape made of special sand which is placed in a mold to form a void or hollow in a casting.

COREMAKERS: Workers who produce cores that are placed in molds to form voids in a casting.

CORUNDUM: Natural abrasive which is about 85 percent aluminum oxide and 15 percent iron oxide.

COUNTERSINK: Chamfering a hole to receive a flat head screw.

COUNTERSINK DRILL: Special drill which cuts a chamfer on a previously drilled hole.

CROSS PEEN HAMMER: Forging hammer in which the peen runs at a 90 degree angle to the handle.

CYLINDER: Supply tank which holds oxygen or acetylene for oxyacetylene welding.

DESIGN: A quality found in or built into objects so that they exhibit such qualities as line, shape, mass, proportion, balance, unity, emphasis, rhythm, harmony and texture. These qualities lend beauty to products that are manufactured.

DIE: Thread-cutting tool used for cutting outside threads. Also, strong metal form used in forging and some types of casting.

DIE CASTING: Method of casting nonferrous metals. Molten metal is forced into a steel mold or die under pressure.

DIE FORGING: The forging of metal using dies instead of a hammer.

DIESINKERS: Skilled metal workers who make impression dies used in forging operations.

DIVIDERS: Tool used for measuring or setting off distances. Also used for laying out arcs and circles.

DRAFT: Taper on a pattern so it can be removed easily from the sand mold without breaking away parts of the mold.

DRAWING OUT: A forging operation designed to lengthen the workpiece.

DRILLING: Cutting holes in material with a tool sharpened at its point.

DRILL PRESS: Powered tool for drilling holes in metal and wood.

DROSS: A scum, usually of oxidized metal or nonmetallic impurities, which forms on top of molten metals.

DUCTILITY: A property of metal meaning the ability of a material to undergo deformation without breaking. Deformation means changing of shape.

ELASTICITY: Property of material enabling it to return to its original shape after deformation (twisting, bending or stretching).

EMERY: Natural abrasive mineral used for grinding and polishing. Consists chiefly of corundum.

EMPHASIS: The principle of design which creates a point upon which major attention is focused. The eye is drawn to this point of focus.

FATIGUE RESISTANCE: Ability or property of a material to resist repeated small stresses.

FERROUS METALS: Groups of metals which are made from iron. They can be distinquished from nonferrous metals in that they can be magnetized and attract a magnet.

FILES: Flat narrow strip of metal of hardened steel with sharp teeth on both sides. Used for cutting away fine shavings of metal.

FLASK: A split (two section) case made of metal. It holds the sand mold used in casting of metals.

FLUX: Paste, liquid or powder used in soldering, brazing or welding to dissolve and remove oxides that might weaken bond between solder and metal being joined. It also breaks down surface tension so solder flows over surface better.

FORGING: Shaping of metal by heating it and then pressing or hammering it.

FORGING TONGS: Hand tool designed for holding hot metal while it is being forged. Types include: straight lip with V notch in each jaw, straight lip, single pick up, curved lip with fluted jaws.

FORM: The element of design which appears as an outline or shape. There are four basic shapes: square, rectangular, round and triangular. Shape is influenced by the purpose of the product.

FORMAL BALANCE: A design principle in which parts of an object are of equal weight, shape and size.

FORMING MACHINE: Also called rolls. Designed to form flat metal sheets into curves and cylinders. Consists of a set of three rollers, a frame and a handle for driving the rollers.

FOUNDRY: Process of forming metal parts by pouring molten metal into a mold cavity.

FUSION: Mixing or combining of molten metals.

GATE: Channel in mold leading from the mold up to where sprue is located.

GOGGLES: Protective glasses set in a flexible frame that fit snugly against the face.

GREEN SAND CASTING: Method of casting using mixture of sand and clay. Mold is destroyed after single use.

HACKSAW: Metal cutting hand saw consisting of a metal frame and a narrow fine-toothed blade.

HAMMER OPERATORS: Iron workers who operate huge power hammers and presses in forging operations.

HAMMERSMITH: Worker in a forge who supervises a work crew, interprets blueprints, determines hammer force and heat of workpiece.

HAND DRILL: Tool for holding a bit for drilling metal or wood. Consists of handle, crank, gears and chuck for holding the drill.

HARDENING: Heating and cooling of steel to make it more resistant to denting and bending. Steel must be heated to certain temperatures and then quenched in water, oil or brine, depending on the type of steel being treated.

HARDNESS: A property of a material concerning its resistance to surface abrasion or penetration.

HARDY: An anvil tool which is designed for cutting both hot and cold metals.

HARDY HOLE: Square hole in the body of an anvil. It is used for holding square-shank tools such as hardies, swages and fullers.

HARMONY: Good design resulting in different parts of an object going well together.

HAWK-BILLED SNIPS: Tin snips with narrow, curved blades designed for making curved cuts.

HEAT:Energy of motion in a substance relating to molecules of the substance.

HEATERS: Metal workers who operate furnaces and heat metal to proper working temperature for forging operations.

HEAT TREATING: Process of heating and cooling steel in certain ways to change its properties.

HIGH-CARBON STEEL: Steel having between 0.60 and 1 percent carbon. Sometimes referred to as tool steel.

HORN: Cone shaped part of an anvil used for shaping rings, hooks and curved parts.

INFORMAL BALANCE: Balance which is achieved by a relationship of parts that are unequal.

INVESTMENT CASTING: Process in which wax pattern is coated with investment powder. The powder hardens forming a shell around the wax. Wax is melted, leaving cavity into which molten metal is then poured. Also called "lost wax casting."

LAP JOINT: Weld made by lapping two pieces of metal one over the top of the other. One or both edges may be welded.

LAY OUT: Locate and scribe points on a workpiece where machining and forming are to be done.

LAYOUT FLUID: A liquid intended to be painted on surfaces prior to marking them for layout.

LINE: One of the elements in design. It is a visual quality which gives direction to an object. Lines of an object can be straight, curving or jagged.

LOW-CARBON STEEL: Steel containing about 0.15 to 0.30 percent carbon. Often called mild steel. Carbon content is not high enough to harden the steel to any appreciable degree.

MACHINE BOLTS: Bolts with square or hexagonal heads.

MALLEABILITY: Ability of a metal to be shaped by rolling or hammering when cold. Known as a "property."

MASS: An element of design relating to the size or bulk of an object. It usually has three dimensions—length, width and height. The appearance may be round, square, irregular or some other geometric shape.

MEDIUM-CARBON STEEL: Steel containing about 0.30 to 0.60 percent carbon.

MELTING FURNACE: Small furnace similar to a kiln capable of melting various metals to molten state.

MILD STEEL: See LOW-CARBON STEEL.

MOLDERS: Workers who ram the sand in preparation of molds for casting.

MOLDING BOARD: Platform on which cope and drag are placed during ramming of mold.

MUSHROOM HEAD: A deformation of the head of tools which are driven by a striking device such as a hammer. Use of tools with mushroomed heads is considered dangerous.

NC: Abbreviation for National Coarse, a standard thread series for fasteners.

NONFERROUS METALS: Metals having no iron in them. Aluminum, copper and brass are examples.

OXYACETYLENE WELDING: Welding process which uses a torch. Fuel for the torch is a mixture of oxygen and acetylene gases. The flame burns at more than 6000 deg. F.

PATTERNMAKER: Skilled worker who prepares patterns used in making molds.

PEEN: To flatten by hammering with a peen. Also: Rounded or wedge-shaped head of peening hammer.

PEENED SURFACE: Decorative surface placed on metal by striking it repeatedly with light blows

from a hammer.

PERMANENT MOLDS: Reusable molds designed for producing large quantities of identical pieces. Mold material is steel. Such molds are used primarily for casting nonferrous metals.

PRICK PUNCH: Small center punch also known as a layout punch. Point is ground at an angle of 30 degrees. It is used to accurately mark holes and other locations to be machined.

PRITCHEL HOLE: Hole in the body of an anvil used for bending small rods and punching holes in metal.

PROCESSES: All activities which are engaged in to change raw material into more usable products. For example, melting, molding, cutting and forging are all processes to make metal into more usable forms.

PROPORTION: A principle of design, proportion refers to pleasing relationship of dimensions or parts. Certain ratios are more pleasing than others. Rectangles, ovals and free-form shapes are usually more pleasing than squares or circles.

PUDDLE: Part of the weld that is melted (molten) due to the heat of welding.

QUENCHING: Rapid cooling of metal by immersion in a cooling liquid such as oil, water or a brine solution.

RAM: To pack sand into a cope or drag in preparation of a mold.

REAM: To enlarge a hole to exact size with a reamer.

REGULATOR: A valve which controls flow of gases for processes such as welding by oxyacetylene.

RHYTHM: A design principle which uses repetition of elements, color or texture to create a feeling of movement.

RIDDLE: A sieve through which mold sand is screened while it is being added to the mold.

RISER: A hole in the cope of a sand mold to allow escape of gases generated during casting operations.

RISER PIN: Metal or wooden pin used to form hole in mold so metal can expand and ensure complete filling of mold.

RIVET: Soft metal shaft with head at one end. It is inserted through holes in metal as a fastener. Other end is peened (enlarged) to hold parts together.

RIVETING: Fastening parts together with rivets.

ROLLING: Process of forming and shaping metal by passing it through a series of power-driven rolls.

ROTARY MACHINE: Sheet metal machine designed to perform beading, crimping, burring, wiring and turning operations. Consists of rigid cast iron frame fitted with shafts, gears and several different sets of rollers.

SCALE: Oxidation on surface of metals heated in presence of air.

SCREW PITCH GAUGE: Gauge for measuring number of threads per inch on threaded parts.

SCRIBER: Pointed steel instrument used to scribe (or scratch) lines on most metal surfaces.

SILICON CARBIDE: Artificial abrasive made by heating coke, sawdust, salt and pure silica sand.

SLAG: Nonmetallic byproduct of welding which attaches itself to the bead.

SOLDER: An alloy of metals having a lower melting point than metal it is joining. Usually consists of a 50/50 mixture of tin and lead.

SOLDERING: Joining metal with a mixture of tin and lead which melts at lower temperature than the metal being joined.

SOLDERING COPPER: Squared shaft of copper with a handle attached to it. It is heated and used to heat material being soldered.

SPINDLE: Rotating shaft in a drill press which holds drill.

SPOT WELDING: An electric welding process. Heat is produced by resistance to flow of electric current through the metal being welded.

SPRUE PIN: Tapered wood or metal pin that is used to make a hole in the cope during ramming of a mold. The hole provides access to the mold when the metal is poured.

SQUARING SHEARS: Stationary machine designed for cutting sheet metal.

STOVE BOLTS: Bolts with coarse threads that make a loose fit with a square nut.

STRAIGHTEDGE: Precision tool for checking the accuracy of flat surfaces.

STRAIGHT PEEN HAMMER: Forging hammer with the peen (ridge) running parallel to the handle.

STRAIGHT TIN SNIPS: Tin snips designed for cutting along straight lines and on the outside of large curves.

STRIKING AN ARC: Process of establishing a current flow so electric arc welding can commence. Electrode is brushed across the workpiece to start the arc. Then it is lifted away slightly to maintain the arc.

STRIKING OFF: A step in producing a mold. A strike board is slid across the frame of the cope to remove excess sand and level off the sand rammed in the cope.

SWAGE: Anvil tool designed for smoothing round stock. Consists of two parts each having a rounded trough across its face. One part fits into the anvil body; the other is hand held.

SWEAT SOLDERING: Method of soldering in which mating surfaces are coated with a thin layer of solder and then placed together and heated. Heat

draws solder into joint where it cannot be seen.

TANTALUM: A white, ductile, malleable metal with a melting point of 5162 deg. F.

TAP: Thread-making tool used to cut inside threads.

TEXTURE: An element of design which has to do with roughness or smoothness of surfaces.

TEMPERING: A metals process used to remove a certain degree of hardness and brittleness of steel and increase its toughness. Also called "drawing the temper."

TEMPLATE: Pattern used in layout of metal or wood parts.

TINNING: A coating of the soldering metals done in preparation of joining them.

TITANIUM: Space age metal which compares favorably to low alloy steel in strength but weighs about half as much. It can be heat treated while retaining high strength up to about 1100 deg. F.

TOOL DESIGNER: An engineer who specializes in thinking up designs for tools, jigs and fixtures to aid in the manufacture of specific products. He or she may also redesign tools to improve their efficiency.

TOOL STEEL: See HIGH-CARBON STEEL.

TRIPOLI: Common cutting compounds used as a buffing agent. Made from limestone having a high silica content. It is usually mixed with grease to form a stick or cake.

TUNGSTEN: A silver white, ductile metal with a melting point of 6116 deg. F., highest of any metal.

TWIST DRILL: Metal cutting tool which cuts holes in material. Consists of a metal shaft with two spiraled grooves called flutes running around the shaft. End is sharpened to a point. Cutting lip is formed where sharpened end meets edge of a flute.

UNITY: A principle of design that seems to bring various parts of an object together as a whole. The parts seem to belong together and the eye moves across and through the various parts with ease.

UPSETTERS: Metal workers who operate presses which shape metal using dies.

UPSETTING: Forging operation used to increase the thickness of a piece of stock metal at a given point.

VENT: Small opening extending from mold cavity to outside of mold. Its purpose is to provide an escape for air, steam and gases as the molten metal is poured into the mold.

WASHER: Flat thin ring of metal used in assemblies with bolts to ensure tightness, prevent leakage or relieve friction.

WELD SYMBOLS: All of a standard set of individual ideographs made up of lines and special shapes which make up a special type of "shorthand" used in blueprints to tell welders what specifications are required for a certain weld. They appear as part of the welding symbol which is an assembly of many weld symbols.

WELDING: Metalworking process for joining metals. Parts are heated at the joint only and then the molten parts are allowed to flow together. This may be accomplished with or without pressure.

WELDING ROD: Rods made up in various diameters to be used as filler metal in welding.

WELDING SYMBOL: The assembled weld symbols used on a blueprint to indicate all instructions and specifications for making a weld. Includes as many as eight graphic markings: reference line, arrow, basic weld symbols, finish symbols, dimensions and other data, supplementary symbols, tail and specifications and process or other references.

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INDEX

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A career in the ever-expanding field of electricity and electronics offers the youth of America an opportunity for satisfying and productive employment. This exploratory course is intended to familiarize the student with Basic Principles of ELECTRICITY and their PRACTICAL APPLICATIONS.

The course emphasizes how many ways Electricity affects our everyday living. It helps the student acquire Safe Work Habits and develop skills in Using Tools in Simple Electrical Construction.

These instructional units provide, in easy-to-understand language, information on Sources of Electricity, Types of Circuits, Operating Principles of Electric Motors, Measuring Instruments, Generators and Transformers, Inductance, Capacitance, and an Introduction to Solid State Devices.

It is the desire of the authors that this text will contribute much toward the General Educational Development, Career Preparation and Enjoyment of the students who use the text.

TO THE STUDENT

Electricity is a fascinating subject to study. As you progress through the basic principles upon which modern knowledge of the electrical phenomena is based, you will realize the vast importance of the role that electricity plays in our everyday lives. It is one of the great forces harnessed by the scientists of the twentieth century.

You will find that the simple projects which you build in connection with your studies will demonstrate and give understanding to the laws and applications of electricity. Your interest will be stimulated. Electricity is an exciting science.

The study of electricity is not only for the scientist. This force has molded our civilization and raised our standard of living above any in the world. Having an understanding of its principles and applications is a basic requirement of any well-educated person. Electricity offers you a challenge. Will you accept it?

HOWARD H. GERRISH
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CONTENTS

ELECTRICITY AND ELECTRONICS LAB SAFETY

All the rules of general safety used in other school labs apply equally to the electrical lab. So that you are aware of these, some of the more important ones will be repeated.

1. Don't fool around! Many painful accidents occur by the careless and thoughtless antics of the so-called "clown."
2. Your teacher is there to help. Ask for his or her approval before starting work. This will save time and help prevent accidents.
3. Report any injury at once. A small cut can develop into serious trouble if not properly cared for.
4. Your eyes are a priceless possession. Wear safety goggles when grinding or working where sparks or chips are flying.
5. Keep the floors around your work area clean and free of litter which might cause someone to slip or stumble.
6. Use tools correctly and do not use them if they are not in proper working condition.
7. Observe proper ways of handling and lifting objects. Get help to lift heavy objects.
8. Do not talk to or attract the attention of a friend when operating machinery.
9. Never leave a machine running or running down. Wait for it to stop before leaving it.
10. Obtain permission before using any power tools.

SPECIAL SAFETY RULES FOR THE ELECTRICITY—ELECTRONICS LAB

1. Although no dangerous voltages are used in the projects in this text, for the normal healthy person, a surprising electric shock may be experienced under certain circumstances. Observe safety rules concerning each project and be particularly careful not to contact any wire or terminal which is connected to B+ or high voltage.
2. A precaution used by television service technicians might well be practiced by you when testing your projects. ALWAYS KEEP ONE HAND IN YOUR POCKET. If two hands are in contact with a circuit, a current will flow across your body and is more dangerous.
3. Do not apply voltage or turn on any device until it has been properly checked by the instructor.
4. A project turned off and disconnected from the power source can still contain a charge of electricity. Always short out capacitors with an insulated screwdriver before attempting to work on or repair a project involving a capacitor.
5. If your project should blow a fuse in the main power line, do not turn it on until the trouble is discovered and remedied.
6. Always stand a safe distance from any project when it is turned on for the first time.
7. Know where the fire extinguishers are placed in your laboratory.
8. Certain components such as resistors and vacuum tubes get hot while operating. Wait for them to cool before attempting to remove them.
9. When turning on your project, observe carefully the power supply.
10. Be sure equipment is in proper working order before use. Frayed cords and plugs are a major source of accidents.
11. Ask for instruction before using any piece of electronic test equipment. One wrong connection can destroy an instrument and thus deprive you and others of its use until repaired. The repairs can be expensive.

SAFETY QUIZ

1. Why does a TV service technician make tests on a live circuit with one hand in his pocket?
2. Describe the times when safety goggles should be worn in the electrical lab.
3. Why should you stand away from your project when it is turned on the first time?
4. Which parts of a device might become hot during operation?
5. Why is a project still dangerous, even after the power is turned off?
6. If a device blows out a fuse in the power line, should you replace the fuse and again operate the device? Explain.

Unit 1
THE ELECTRON

After studying this unit, you will be able to answer these questions:

1. **What is the nature of matter?**
2. **What is the electron theory?**
3. **How does an electric current flow through a wire or conductor?**

ELECTRICITY—AN INTRODUCTION

Spectacular discoveries and inventions have been realized in the science of electricity and electronics. The use of electricity has become such a common part of our everyday life, that one seldom thinks about the vast network of wires that makes it possible for us to use the great invisible force called electricity.

You turn on your radio or television to hear and watch your favorite program. You snap a switch on the wall and immediately a room is filled with light. Electricity is commonly used for refrigeration, cooking, washing, and drying clothes. It is used to facilitate heating, cooling, mixing food, kitchen ventilation, garbage disposal, and for a multitude of other uses. Electricity powers our modern computers.

In the last few years electricity and electronics have made it possible to walk on the moon and explore the mysteries of outer space.

Whatever a person's chosen profession or vocation, a fundamental knowledge of electricity should be a part of his or her general education.

Electricity is not new. It has been in existence since the beginning of time. Only in recent years have scientists explored the phenomena of electricity and proposed theories as to its nature. It seems strange that we do so many things with electricity and yet no scientist has ever seen it. One might call it "the great invisible wonder of the twentieth century."

Over two thousand years ago the Greeks discovered that if a yellowish brown translucent resin called "amber" was rubbed vigorously with a cloth, it would attract small pieces of dust and dried grass. The Greeks believed that these amber fossils were living stones. They called them "elektron." From this Greek name is derived our present name "electronics."

An interesting project, which demonstrates these properties of static electricity, may be found in the STATIC BIRDS, Project 2. These "static birds" will be amusing and educational.

As we are interested in the science of electronics, a more thorough understanding of the electron is necessary.

All matter of substance is made up of molecules. Let's see just what that means. If you could take a glass of water and keep dividing it and dividing it, you would finally reach a point at which no further division could be made and still keep the identity of the water. We could say that a MOLECULE is the smallest division of a substance which could be made without destroying the identity or properties of the substance.

You know that water is a chemical combination of hydrogen and oxygen. We refer to it as H_2O. Neither hydrogen nor oxygen alone has any resemblance to water at all. They are entirely different, but when united, molecules of water are formed. These particles of hydrogen and oxygen which make up the molecule of water are known as atoms.

The ATOM is the smallest particle of an element. There have been over a hundred different elements discovered. The chemist arranges

them in order of their weights, or groups them according to similar properties. This arrangement is called the Periodic Table of the Elements.

You are familiar with elements such as copper, silver, and iron. Carbon is used in your "lead" pencil. There are tin, lead, gold, uranium, as well as many others. The Greeks thought that all matter was made up of these atoms, and that the atom was the smallest particle that could exist. This theory was advanced by the English physicist John Dalton in 1808.

The atom has been smashed to study it further. Physicists have explored the structure of the atom itself. They have discovered that the atom contains a center called the NUCLEUS. This nucleus which contains most of the mass of the atom is made up of a certain number of positive particles of electricity called PROTONS and a number of neutral particles of electricity called NEUTRONS. Revolving around this core or nucleus, in orbits, are negatively charged particles of electricity called ELECTRONS, Fig. 1-1.

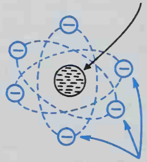


Fig. 1-1. Electrons in orbit around the nucleus.

CLASSIFICATION OF ELEMENTS

Elements are classified in the Periodic Table of the Elements by the number of protons in the nucleus. This is the ATOMIC NUMBER. Also, elements are classified by the number of protons and neutrons in the nucleus. This is the ATOMIC WEIGHT or MASS NUMBER. The examples of atomic models shown in Fig. 1-2 will help you to understand this.

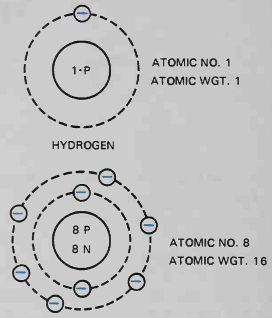


Fig. 1-2. Atomic models of hydrogen and oxygen.

IONIZATION

Generally all atoms have electrons in orbit equal to the number of protons in the nucleus. Therefore the atom is electrically in balance or neutral.

Some atoms hold their revolving electrons rather loosely and if excited by a collision with other atoms or by friction or by chemical action, the atoms will lose or gain electrons. If this occurs, the atom will become unbalanced with either an excess or a deficiency of electrons. This atom is said to be IONIZED. If the atom has lost some electrons, it would then have more protons and would become positively charged or a positive ion. On the other hand, if the atom gained some electrons, it would have more electrons and become negatively charged, or a negative ion.

CONDUCTORS AND INSULATORS

Some elements, particularly the metallic elements such as copper, silver, aluminum, and others, hold their electrons rather loosely. A very small force will cause them to give up some electrons. Such an element would be considered as a good conductor of electricity. Electrical energy is transferred through the conductor by the free movement of electrons from one atom to the next atom as shown in Fig. 1-3.

Fig. 1-3. The transfer of energy by electron movement is called electric current.

As an electron is added to one end of the conductor, an electron leaves the other end of the conductor. This transfer of electrons through the conductor is called CURRENT or ELECTRICITY. It is important to observe carefully that the actual electrons move only short distances as they displace each other, but the actual transfer of energy from one end of the conductor is almost instantaneous.

The speed of this transfer has been measured and found to be near 186,000 miles per second or 300,000,000 metres per second.

A material which will allow the free movement of many electrons would be a good CONDUCTOR of electricity. On the other hand, if a material allowed only a few electrons to move freely, it would be considered an INSULATOR. SEMICONDUCTORS are elements which are neither true conductors or insulators in their ability to permit electrons to flow. Opposition to the flow of electrons created by the material is called RESISTANCE. A good conductor has a low resistance; an insulator has a high resistance and semiconductors lie somewhere in between. Some familiar materials of each type are listed in the table in Fig. 1-4.

CONDUCTORS	SEMICONDUCTORS	INSULATORS
Silver	Silicon	Air
Copper	Germanium	Glass
Aluminum	Selenium	Porcelain
Brass		Rubber
Iron		Bakelite

Fig. 1-4. Examples of materials which may be used as conductors, semiconductors, and insulators.

LAW OF CHARGES

One of the most important lessons in the study of electrons and electrically charged particles is the attraction and repulsion of differently charged particles: LIKE CHARGES REPEL AND UNLIKE CHARGES ATTRACT. You MUST understand this thoroughly. This principle will be used many times in future lessons to explain the concept of electricity.

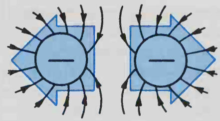


Fig. 1-5. LIKE CHARGES REPEL each other, due to opposing electrostatic fields. Repulsion is indicated by large colored arrows.

Existing in space around a charged body will be an invisible field of force called an ELECTROSTATIC FIELD. This phenomenon is easily demonstrated by experiments conducted in the laboratory. These static fields of force and their direction of force are represented by the small arrows in Figs. 1-5 and 1-6. Fig. 1-5 shows the case of two negatively charged bodies. Note the fields repel each other and cause the bodies to move away from each other. In Fig. 1-6, the fields are attracted to each other and create a force which would cause the bodies to move toward each other.

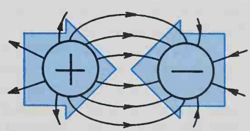


Fig. 1-6. UNLIKE CHARGES ATTRACT each other, due to attractive electrostatic fields. Attraction is indicated by large colored arrows.

The force of the attraction and repulsion of charged particles was explored by the famous scientist, Charles Coulomb. To describe the difference in charge between two bodies, it would be insignificant to say that this body has one or two more electrons than the other, because an electron is such a tiny particle of electricity.

A more practical unit of measurement would be a large quantity of electrons known as the COULOMB. A Coulomb represents 6,240,000, 000,000,000,000 electrons or 6.24×10^{18} electrons.

WIRE SIZES

Conductors or wires for electrical circuits are manufactured in a variety of sizes, materials, and with various insulation coverings. A number has been assigned to each particular size known as the American Wire Gage. For example, a common size wire used in the wiring of your home is AWG No. 12. As the number grows larger, the actual size of the wire decreases and vice versa. In the table shown in Fig. 1-7, several common sizes are listed giving

AWG SIZE	D (APPROX.) IN MILS	CROSS SECTION AREA CIRCULAR MILS
8	128.0	16,500
10	102.0	10,400
12	81.0	6,530
14	64.0	4,110
16	51.0	2,580
18	40.0	1,620
20	32.0	1,020
22	25.3	642
24	20.1	404
26	15.9	254

Fig. 1-7. Sizes of wires commonly used for electrical circuits.

their diameters in mils, (one thousandth of an inch) and their cross sectional area in circular mils. A circular mil is the cross sectional area of a wire .001 inches in diameter. The area of a conductor in circular mils is found by squaring the diameter of the conductor measured in mils. For example: A wire has a diameter of 50 mils, what is its area in circular mils?

$$50^2 = 2500 \text{ cir. mils}$$

Do not be confused with the term circular mil. It is different than a square mil and is a smaller area. The use of the circular mil saves a great deal of cumbersome mathematics in the computation of sizes of wires.

An American Standard Wire Gage is shown in Fig. 1-8. You will want to measure an assortment of wires with this gage.

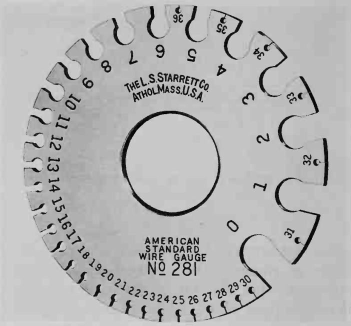


Fig. 1-8. A gage used to determine wire size. (L.S. Starrett Co.)

QUIZ — UNIT 1

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Like charges ______________ each other.
2. Unlike charges ____________ each other.
3. The word electronics is derived from the Greek word _________.
4. The smallest division of a compound that can be made without the compound losing its identity is known as a ____________.
5. Compounds are made up of ___________, and were once considered the smallest particle that could exist.
6. Elements are arranged in a table called the _________ by their atomic _________ and their atomic _________.
7. List four good conductors of electricity.
8. List four good insulators.
9. When an atom has lost or gained some electrons, it is said to be ____________.
10. Opposition to the flow of electrons in a substance is known as _____________.
11. A neutral particle of electricity is called a ____________.
12. A positively charged particle of electricity is called a ____________.
13. A negatively charged particle of electricity is called an ____________.
14. A material which has resistance in between a conductor and an insulator is a ____________.

Unit 2

VOLTS, AMPERES, OHMS

After studying this unit, you will be able to answer these questions:

1. **What is the unit of electromotive force called a volt?**
2. **How is an electrical current measured?**
3. **How is resistance to the flow of current measured?**

VOLTS

An interesting experiment performed in the laboratory is shown in Fig. 2-1.

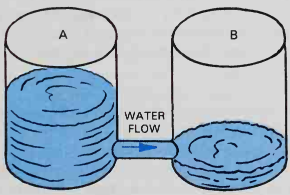


Fig. 2-1. Water will flow until the levels in the two containers become equal.

Container A is connected to container B by a pipe. When A is filled with water, the water will flow through the pipe to B until the level of water in both containers is the same.

If we should take two terminals and cause one to have an excess of electrons (negative) and the other with fewer electrons (positive), then connect a conductor (pipe) between them, electrons would flow from one to the other until the number of electrons on one became equal to the electrons on the other, Fig. 2-2.

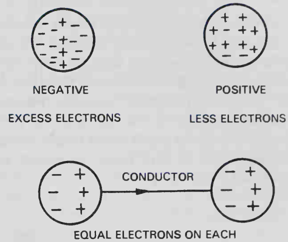


Fig. 2-2. Unequal electrical charges will cause electrons to flow.

What caused the water to flow? It was the difference between the level or height of the water in each container. What caused the water to stop flowing? The level or height of water in each container became the same or equal. What caused electrons to flow between the two oppositely charged bodies? It was the difference between the number of electrons. In electricity this is called the potential difference. What caused the electrons to stop flowing? The number of electrons became equal and the potential difference became zero. It is easy to understand that electrons flowed because of a potential difference which created a force, called an ELECTROMOTIVE FORCE or VOLTAGE. This force existed only during the time that the electrons were unevenly distributed between the two terminals.

In the case of the water, the force which caused the water to flow may be measured in pounds per square inch. The greater the difference between the two levels, the greater the force.

In the case of the charged terminals, the force which caused the electrons or current to flow is measured in volts, sometimes referred

to as POTENTIAL DIFFERENCE or ELECTROMOTIVE FORCE (EMF). The letter symbol for voltage is the letter E. In semiconductor circuits the letter V is used for volts. The actual value of one volt is accurately kept by the Bureau of Standards in Washington, D.C.

AMPERES

If you wished to do so, you might measure the number of gallons per minute flowing through a garden hose. You would only need to see how many gallon cans were filled in one minute. The flow of water through the hose could be considered as the quantity of water that passed any given point in the hose, and the flow is the same at any point at which you might measure, Fig. 2-3.

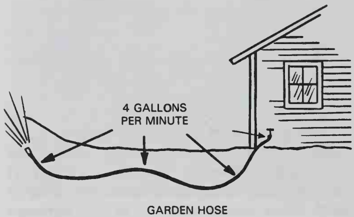


Fig. 2-3. The flow of water in the hose is the same at any point.

In the case of electric current, it can be measured by a definite quantity of electrons passing any given point in the conductor. We learned in Unit 1, that the unit of quantity of electrons is known as the coulomb, and represents a very large number of electrons. If one coulomb of electrons passes a fixed point in the conductor per second, one AMPERE of current is said to be flowing. This unit of measurement was named in honor of the French scientist, Andre Ampere. The symbol for current is the letter I.

CURRENT FLOW

Some textbooks on electricity describe the flow of electricity as flowing from positive to negative. In this text, CURRENT will always be assumed to be "electron flow" and will flow from negative to positive. See Fig. 2-2. In our study of electricity and electronics, this will be an important fact to remember.

CONDUCTOR SIZE AND RESISTANCE

If the power company is going to conduct electric power to cities, homes, and factories, the size and kind of wires used become an important consideration. The material from which a conductor is made must have a low resistance and sufficient size to carry the electric current, as well as physical strength to withstand the rigors of snow, ice, and wind.

Silver is the best conductor but it is very expensive. Copper is also an excellent conductor. It has high tensile strength, but it is heavy and quite expensive. Aluminum offers some distinct advantages for use in high voltage transmission lines. It conducts electricity about sixty percent as well as copper, and is light and relatively inexpensive. Because of its light weight, it is possible to run long spans between supports and thus reduce the number of supports needed.

An example of resistance and wire sizes may be taken closer to home. The lights in your home can satisfactorily operate with wire size No. 14. An electric range may require a No. 6 wire or larger to feed the necessary current to the range.

In the table, Fig. 2-4, are listed several sizes of copper wire and the resistance per 1000

WIRE SIZE AWG	RESISTANCE OHMS/1000 FT.
6	.465
8	.739
10	1.18
12	1.87
14	2.97
16	4.73
18	7.51
20	11.9
22	19.0
24	30.2

Fig. 2-4. Table showing resistance offered by several sizes of solid copper wire.

feet of wire. Study this table and notice how the resistance increases as the wire grows smaller.

PROBLEM: What is the resistance of 300 feet of No. 16 solid copper wire? Referring to the table, No. 16 wire has a resistance of 4.73 ohms per thousand feet. Therefore the resistance of 300 feet would be,

$$\frac{300}{1000} \times 4.73 =$$

$$.3 \times 4.73 = 1.419 \text{ ohms}$$

Another example will show a different use of this table: A wire must be run over a distance of 500 feet and the resistance cannot exceed one ohm. What size wire should be used? Explanation: As 500 feet is one half of one thousand, it is only necessary to look at the table and discover which size wire has a resistance of less than two ohms per 1000 feet. You would select No. 12 because,

$$.5 \times 1.87 = .935 \text{ ohms}$$

CONDUCTANCE

Up to this point we have only considered copper and aluminum as conductors. You should understand that as the resistance of a wire decreases, its ability to conduct increases and vice versa. So you could state the current carrying capacity of a wire either by stating its resistance as measured in ohms or its ability to conduct. Conductance will be studied in a later lesson, when computing parallel circuits. Referring to Fig. 2-5, you will observe the relative conductivity of several common materials. This table is based on the fact that silver is the best conductor and therefore is assigned the value 100. All other materials are less, based on a percentage compared to silver.

MATERIAL	CONDUCTIVITY
Silver	100
Copper	98
Aluminum	61
Tungsten	32
Iron	16
Carbon	.05

Fig. 2-5. Comparing conductivity of several materials.

It is apparent from Fig. 2-5 why carbon is used as a resistive material in electric and radio circuits. It has a very low ability to conduct.

STRANDED CONDUCTORS

There are occasions when one solid wire is not satisfactory for a particular use. One case would be for use in a wire that will receive a lot of bending such as an appliance cord. If made of one solid wire, it would be stiff rather than flexible and would break after a few bends. It is more practical to make up a cord of several strands of smaller wire. Another case is where a group of conductors is used instead of the solid conductor in very large power transmission lines. It is necessary in this case to give flexibility so that the conductor can be handled and bent. Standard cables are made with 7, 19, or 37 strands of wire.

OHMS

If your garden hose is a five-eights inch hose, you can see that there are limits to the amount of water the hose could carry. If you need more water, you could buy a larger hose or even use two hoses. In other words, the size and internal friction of the hose limit the quantity of water which will flow through it, without damage to the hose.

The same applies to an electrical conductor. A certain size and kind of wire offers a definite opposition or limitation or RESISTANCE to the flow of an electric current. If large currents are forced through the conductor which exceed its ability to carry current, the wire will become hot and destroy itself by melting. Many homes burn down each year because the wire used is inadequate in size to carry current necessary for today's modern living.

In a properly wired home there are either fuses or circuit breakers installed at the electrical service entrance switch. These are safety devices. A fuse will burn out or a circuit breaker will open if the circuit is forced to carry too much current.

The resistance to the flow of current is measured in OHMS. One ohm of resistance will

allow one ampere to pass when one volt pressure is applied.

The resistance of a conductor will depend upon:

1. The LENGTH of the conductor. If a wire has a resistance of one ohm per hundred feet, then 1000 ft. would have a resistance of 1 x 10 or 10 ohms.
2. The SIZE of the conductor. The larger the wire, the less resistance.
3. The MATERIAL used for the conductor. Materials differ in their ability to conduct electricity.
4. HEAT. In common conductors such as copper and aluminum, the resistance increases as the temperature increases.

RESISTANCE

One might think that resistance is a very undesirable thing to have in an electrical circuit. This is not so. Resistance is purposely introduced into circuits to produce desired results. Also, resistance is used to produce heat. The energy used up in a resistance unit appears as heat. An electric range has resistance units which are the cooking surfaces on top of the stove. Light bulbs contain resistance units which get white hot and produce light.

The electrical circuits which you will construct in the EXPERIMENTER, Project 1, will help you to understand the flow of current through a resistance. In this project, the electricity will produce light. The switches will demonstrate common methods of turning the lights "on" or "off."

Resistance in any circuit is the only component that uses up power and causes losses in the line. So any load on an electrical circuit that uses power can be represented by a resistor.

The letter symbol for resistance is R. Its symbol in an electrical circuit is shown in Fig. 2-6.

Fig. 2-6. Electrical symbol for resistance and Greek letter meaning ohms.

Whenever you see the Greek letter "omega" which appears as Ω, it will mean OHMS. An example is illustrated in Fig. 2-6 where R is equal to 100 ohms or 100 Ω.

Resistors may also be variable in value. Variable resistors are called POTENTIOMETERS or RHEOSTATS depending on how they are used. The symbol for a variable resistor is shown in Fig. 2-7

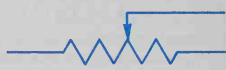


Fig. 2-7. Variable resistor symbol.

RESISTOR COLOR CODE

In your electronics studies, you will be using various kinds of resistors. Many carbon type resistors have bright colored bands. These bands will tell you the value of the resistors in ohms. The resistor COLOR CODE, Fig. 2-6, is for you to study. This should be memorized.

COLOR	NUMERICAL FIGURE	MULTIPLIER	TOLERANCE
BLACK	0	× 1	
BROWN	1	× 10	
RED	2	× 100	
ORANGE	3	× 1000	
YELLOW	4	× 10,000	
GREEN	5	× 100,000	
BLUE	6	× 1 Million	
VIOLET	7	× 10 Million	
GRAY	8	× 100 Million	
WHITE	9	× 1000 Million	
SILVER	-	× .01	±10%
GOLD	-	× .1	±5%
NONE	-	- - -	±20%

Fig. 2-8. Resistor color code.

READING RESISTOR COLOR CODE

To identify a resistor from the color code, hold the resistor in your hand with the color bands on the LEFT. The first band color is the first number of the value. See Fig. 2-9. The sec-

ond band color is the second number of the value. The third band color tells you to multiply the first two numbers by this factor.

For example, in Fig. 2-9, a resistor with bands of BROWN, BLACK, GREEN, AND SILVER represents 1,000,000 Ω or 1 megohm.

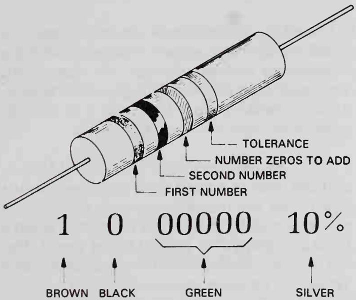


Fig. 2-9. How to read the resistor color code.

The fourth band, silver, tells you how accurate the resistor must be in order to pass inspection. This resistor is ±10 percent. It could actually measure as high as 1.1 megohms or as low as 900 KΩ and still be acceptable (10 percent above to 10 percent below specified value).

The more accurate a resistor is, the more expensive it becomes. Most expensive equipment will use ±5 percent resistors and ±1 percent resistors. Working with the color code is the best way to learn it. You will be given many chances to practice.

CHIP SAYS:

"Caution: When using the apliance cord type of wire, remember that each little strand of the wire is a conductor. Frayed wires, not properly connected, can make the sparks fly. It is the practice of a good technician to always coat the ends of a stranded wire with solder. This is called tinning. This keeps the fine wires in one group and allows you to make a good connection around a terminal."

GREAT SCIENTISTS
ALESSANDRO VOLTA (1745-1827)

Alessandro Volta is famous for his experimentation with a series of zinc and silver plates in a pile, each separated by a sheet of moistened paper, leading to the discovery of the voltaic cell. The experiment is known as the "voltaic pile."

Also credited to his genius, is the invention of the condenser or capacitor and the electroscope used for detecting an electric charge.

GEORGE SIMON OHM (1787-1854)

George Simon Ohm developed the mathematical equations we work with today, known as Ohm's Law. The unit of resistance was named in his honor.

ANDRE MARIE AMPERE (1775-1836)

Andre Marie Ampere is celebrated for his work in demonstrating the relationship between electricity and magnetism. The unit of measurement of electric current, the ampere, is named in his honor.

QUIZ — UNIT 2

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. The unit of quantity of electricity is ______.
2. The unit of electrical current is ______.
3. Potential difference is measured in ______.
4. Electromotive force is measured in ______.
5. Electrical pressure is measured in ______.
6. Electrical resistance is measured in ______.
7. Name four factors affecting the resistance of a conductor.
8. Resistance ______ as the wire length increases.
9. Resistance ______ as the wire size decreases.
10. Draw the symbol for a resistance unit in a circuit.
11. What is the resistance of 100 ft. of No. 24 copper wire ______?
12. The resistance of a particular circuit cannot exceed one ohm. If the wire is 100 ft. long, which size wire must be selected ______?
13. What is meant by "tinning" stranded wires? Why should this be done ______?
14. Name two factors which must be considered by the power company when selecting a power transmission line.

Unit 3

OHM'S LAW

After studying this unit, you will be able to answer these questions:

1. **What is the relationship between voltage, current, and resistance in a circuit?**

2. **What is Ohm's Law and how we can use it to solve electrical problems?**

3. **What types of switches are used in electrical circuits?**

THE SIMPLE CIRCUIT

All circuits in electricity contain four basic elements.

1. SOURCE of power (such as a battery or generator).
2. LOAD. Some device such as a motor or a lamp which uses power from the source.
3. INTERCONNECTING WIRES or conductors between the source and the load.
4. CONTROL. Some method of limiting or controlling the power supplied by the source. A switch is a control. It turns the power "on" or "off."

In Fig. 3-1, a schematic diagram of a simple circuit is drawn using conventional symbols. You will notice that a battery is used as a source of power; a resistor represents some device which uses power and is the load. Lines show the interconnecting wires. One type of control or switch appears in the circuit.

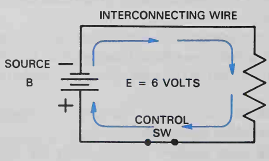


Fig. 3-1. A simple electrical circuit. Note interconnection of elements that make up circuit.

OHM'S LAW

One of the basic laws of electrical circuits is OHM'S LAW. This shows mathematically the relationship between voltage (E), current (I), and resistance (R). A thorough understanding of the use of Ohm's Law will help you to understand how any circuit performs.

If you do not completely understand Unit 2, perhaps now is a good time to review it once again. You will remember that an electric current was caused to flow in a conductor when a force or voltage was applied to the circuit. Fig. 3-1 shows a simple circuit using a battery as a voltage or potential difference source.

R represents the resistance in the circuit and I stands for "intensity" of current flow. E represents electromotive force.

As the voltage of battery (B) is fixed and the resistance of the circuit is fixed, a definite value of current will flow in the circuit. (Note the direction of flow indicated by the arrows.)

If the voltage were increased to twice the value, as in Fig. 3-2, then the current would

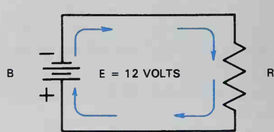


Fig. 3-2. As voltage is increased; the current increases.

also increase to twice its former value. As the voltage increases, the current increases. As the voltage decreases, the current decreases. A mathematician would say that the current and voltage are in direct proportion.

The current flowing in these circuits also depends upon the resistance of the circuit. If we should increase the resistance to twice its value, the current would be cut in half. We may conclude that, as the resistance increases; the current decreases. As the resistance decreases; the current increases. Again, mathematically speaking, the current is in inverse proportion to the resistance.

George Simon Ohm, the German scientist, proved this relationship to be true in his experiments in 1826. The law is named in his honor. OHM'S LAW is stated as,

$$I = \frac{E}{R}$$

Where,

I = current in amperes
E = voltage in volts
R = resistance in ohms

By simple algebra, the formula may be changed to read:

$$R = \frac{E}{I} \quad \text{or} \quad E = IR$$

One may readily see that if any two quantities are known in a circuit, the third quantity may be found. Referring to Fig. 3-3, notice that values have been assigned to E and R.

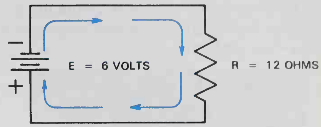


Fig. 3-3. The current equals .5 amperes.

The current is easily computed by Ohm's Law:

$$I = \frac{E}{R} \text{ or } I = \frac{6V}{12\ \Omega} = .5 \text{ amps}$$

If the voltage were unknown and we knew the current and resistance. I = .5 amps, and R = 12 ohms, then:

$$E = I \times R \text{ or } .5 \times 12 = 6 \text{ volts}$$

If the resistance were unknown and the voltage and current were, I = .5 amps, E = 6 volts, then:

$$R = \frac{E}{I} \text{ or } \frac{6}{.5} = 12 \text{ ohms}$$

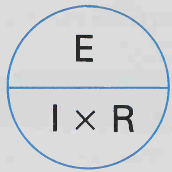


Fig. 3-4. A memory device for Ohm's Law.

If you have difficulty remembering this equation in its three forms; the simple memory device shown in Fig. 3-4 may help.

Place your finger over the unknown quantity and observe what it equals. For example: Put your finger over E, the answer is I × R. Put finger over I, the answer is:

$$\frac{E}{R}$$

Put finger over R, the answer is:

$$\frac{E}{I}$$

Easy? Sure it is.

You must remember that when using Ohm's Law, E, I, and R must be in volts, amperes, and ohms respectively. Study Figs. 3-5 and 3-6. Frequently current is given in milliamperes, which is:

$$\frac{1}{1000} \text{ of an ampere or } .001 \text{ A}$$

You must convert to amperes before using the equation. Studying the following examples will help you to do this:

1 ampere	=	1000 milliamperes
.5 ampere	=	500 mA
.1 amp	=	100 mA
50 mA	=	.05 amps
500 mA	=	.5 amps
10 mA	=	.01 amps
1 mA	=	.001 amps

The best way to learn Ohm's Law is to use it.

1 ampere (Amp)	=	1 ampere
1 milliampere (mA)	=	1/1,000 (.001) ampere
1 microampere (μA)	=	1/1,000,000 (.000001) ampere

Fig. 3-5. Prefixes used in measuring current.

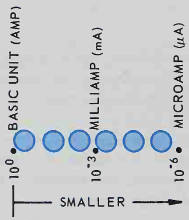


Fig. 3-6. Conversion chart for ampere prefixes.

OVERLOAD PROTECTION OF CIRCUITS

It should be quite clear that a certain kind and size of wire has a specified ability to conduct an electric current. All conductors have some resistance. When a current overcomes this resistance, heat is produced. If a wire is operated within its limitations, this heat is dissipated in the surrounding air and its temperature does not rise excessively. However, if too great a current is forced through the conductor, the temperature will rise to a point where the wire will become red hot and destroy itself. If it is near combustible material, such as in the wall of your home, a fire might result. Overloading a circuit might occur from two causes:

1. Excessive load which draws beyond a safe amount of current.
2. A direct short circuit.

Circuits and appliances are usually protected by a fuse or circuit breaker A FUSE is simply a thin strip of metal which melts at a low temperature. Those used in the home are usually designated 15 and 20 amperes. (Examine your fuse box at home.) This means that if a current exceeds the rating of the fuse, it will melt and open the circuits, thus preventing damage of equipment and danger of fire. The symbol for a fuse as it appears in electrical circuit diagrams appears in Fig. 3-7.

Fig. 3-7. The symbol for a fuse.

DO NOT replace a burned-out fuse with a penny behind it. This is sometimes called an "Abe Lincoln fuse." President Lincoln was a fine man, but his picture on a penny behind a fuse is little security. Some fuses, of course, are made to carry heavier currents. You will find in the entrance switch on your home, fuses of the cartridge type, rated for 100-200 amperes or more. These fuses carry the total current used by all of the circuits in your home and give further protection.

In Fig. 3-8 a simple load in the form of a resistor is connected across a voltage source. If the insulation should become worn or frayed so that wire A could touch wire B, the sparks

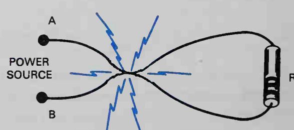


Fig. 3-8. A short circuit between A and B makes the sparks fly.

would fly. This is called a SHORT and it very frequently exists in lamp and appliance cords. Examine your cords at home and perhaps you will find one. These lamp cords are dangerous. You can receive a serious burn from a short circuited lamp cord, as well as danger of an electric shock.

One improved safety device is called the circuit breaker. You will study these in detail in the unit on Magnetism. A CIRCUIT BREAKER is a magnetic or thermal device that automatically opens the circuit when an excessive current flows. See Fig. 3-9. It must be manually reset before the circuit can be used again. Needless to say, the cause of the overload should be investigated and removed before the current is turned on again.

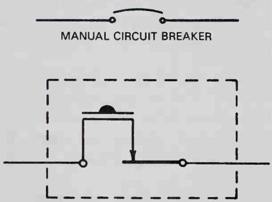


Fig. 3-9. Symbols for circuit breakers.

CIRCUITS AND SWITCHES

There are many varieties of switches that are used in electrical equipment. The student should be familiar with the common type, Fig. 3-10.

If only one wire or one side of a line is to be switched, the single-pole single-throw (SPST) switch is used. If both sides of the line were to be switched, then a double-pole single-throw (DPST) switch would be used. Reference to Fig. 3-10 will show the circuit diagrams for various switches. If a single line is to switch first to one point and then to another, the SPDT switch can be used. If a double line is to be switched to two other points, then the DPDT switch would be used.

Frequently, it is desirable to switch a circuit from two different locations. In this case a three-way switch is used. Perhaps you have such switches in your home which permit you to turn a light "on or off" from two places in a room. The schematic diagram of this hookup is shown in Fig. 3-11.

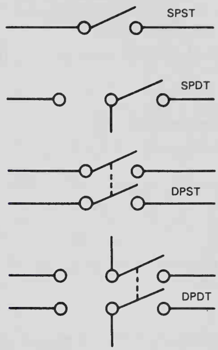


Fig. 3-10. Diagrams of switch types.

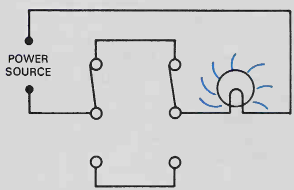


Fig. 3-11. A three-way switch circuit. The light is on.

The light is on, but it can be turned off by moving either switch A or B. In Fig. 3-12 the light is off, but it can be turned on by either switch A or B. Follow the circuit through the switches in each position.

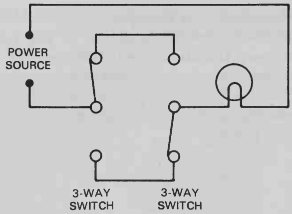


Fig. 3-12. A three-way switch circuit. The light is off.

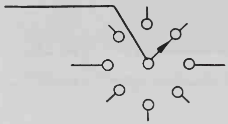


Fig. 3-13. Multiple-pole rotary switch.

In the EXPERIMENTER, Project 1, problem 7, you will gain first-hand experience in connecting three-way switches, so that lights may be controlled from different locations.

A common type of switch used in electrical equipment is the multiple-pole rotary switch. In this switch the rotary contact arm may be connected to one side of a line and the contacts may connect to several circuits. By turning the control knob any desired circuit may be used. Multiple switching operations may be done by mounting several rotary switches on one control shaft, Fig. 3-13.

QUIZ – UNIT 3

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

Draw the circuit diagram for each of the following problems and compute the unknown quantities:

1. A circuit has an applied voltage of 100 volts and a resistance of 1000 ohms. What is the current flowing in the circuit?
2. A circuit which contains 100 ohms resistance has a current of two amperes. What is the applied voltage?
3. A circuit which contains 10,000 ohms of resistance has a current flow of 100 mA. What is the applied voltage?
4. A circuit has an applied voltage of 200 volts which causes a 50 mA current to flow. What is the circuit resistance?
5. An applied voltage of 50 volts causes a current of 2 amperes to flow. What is the circuit resistance?
6. An applied voltage of 500 volts is applied to a circuit that contains 100 ohms of resistance. What is the current flow?
7. If applied voltage is 400 volts and resistance is 20,000 ohms, what is the value of I?
8. A meter indicates a current flow in a circuit of .5 amp. The circuit resistance is 500 ohms. What is the value of E?
9. What applied voltage will cause 500 mA of current to flow through 500 ohms of resistance?
10. What applied voltage will cause 10 mA of current to flow through 1000 ohms of resistance?
11. An electric appliance has a resistance of 22 ohms. How much current will it draw when connected to a 110 volt line?
12. A 110 volt house circuit is limited to 15 amperes by the fuse in the circuit. The following appliances are connected to the circuit. Compute the individual currents for each appliance. What is the total current flowing in the circuit? Will the fuse permit this current to flow?
    Appliance 1 draws 2 amperes.
    Appliance 2 has a resistance of 40 ohms.
    Appliance 3 has a resistance of 20 ohms.

Unit 4

POWER

After studying this unit, you will be able to answer these questions:

1. **What is power?**
2. **What is the relationship between Ohm's Law and the POWER LAW?**

POWER

The rate at which electrical energy is delivered to a load is called ELECTRIC POWER. The unit of measurement of electric power is the WATT, and the symbol for power is P. In electrical circuits the power is equal to the current multiplied by the voltage or $P = I \times E$. Therefore, one watt of power is the result of one ampere of current driven by a one volt force through a circuit.

If a circuit with one volt pressure causes one ampere current to flow for one hour, then one WATT-HOUR of electrical energy has been used. A watt-hour is a relatively small unit of energy. You will be more familiar with the KILOWATT-HOUR which means that energy is used at the rate of 1000 watts per hour. When your parents pay their electric bill, you will notice that they are paying for energy used at so much per kwh or kilowatt-hour. A light bulb in your room may be rated at 100 watts. To keep your light burning for one hour would require 100 watt-hours of electrical energy, and in ten hours it would use one kilowatt-hour of electrical energy.

Another example: A toaster will use five amps of electricity at 110 volts pressure. How much power does it consume? Power equals volts times amperes, so:

$$P = 110 \times 5 = 550 \text{ watts}$$

If you should toast bread for a whole hour, the energy used would equal 550 watt-hours or .55 kilowatt-hours.

Figure out how much it costs for electricity to iron shirts for one hour with an electric iron using 5 amperes of current. The power consumed would be:

$$P = 110 \times 5 = 550 \text{ watts}$$

and in one hour the iron would use 550 watt-hours or .55 kwh. If electricity costs 5 cents per kwh, then the ironing would cost .55 x .05 or two and three-fourths cents per hour.

As power is the product of the voltage and the current in a circuit, one can measure these values by meters and compute the power of the circuits. It is easier to use a special meter, which reads directly in watt-hours as no computation is necessary. Such a meter is on the outside of your house.

By simple algebra we can write the POWER LAW or WATTS LAW in three ways as we did for Ohm's Law:

$$P = I \times E$$

$$I = \frac{P}{E}$$

$$E = \frac{P}{I}$$

Again, the memory device shown in Fig. 4-1 will help you. Place your finger over the unknown quantity and observe what to do with the known two values in the formula.

With only a bit more algebra, the Watt's Law and the Ohm's Law may be combined to give equations to solve for unknown voltage, current, resistance, or power. Fig. 4-2 shows the complete set of equations resulting from combining these laws.

Fig. 4-3 shows a memory device known as the PIRE wheel. It will help you solve problems which involve amperes, volts, ohms, and watts. If the value of any two terms is known, the other two values may easily be found.

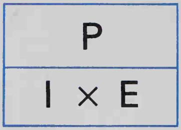


Fig. 4-1. A memory device for Watt's Law.

$I = \frac{E}{R}$	$R = \frac{E}{I}$
$I = \frac{P}{E}$	$R = \frac{E^2}{P}$
$I = \sqrt{\frac{P}{R}}$	$R = \frac{P}{I^2}$
$E = \frac{P}{I}$	$P = I \times E$
$E = I \times R$	$P = I^2R$
$E = \sqrt{PR}$	$P = \frac{E^2}{R}$

Fig. 4-2. Equations used to figure unknown voltage, current, resistance, and power.

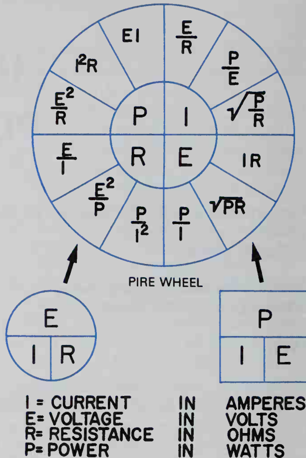


Fig. 4-3. A device which shows the formula resulting from the combination of Ohm's Law and Watt's Law.

HORSEPOWER

We can define ENERGY as the capacity for doing work. Your father wishes you to mow the lawn, but it is so much more comfortable to sit in a lawn chair with a cool drink and a good book. However, you still have the energy stored within you to cut the grass. You still have the force to push the mower. When a force such as yourself, pushes a lawn mower over a certain distance, work is done. WORK is the product of F (force) x D (distance) and is measured in foot-pounds. If the lawn mower requires a ten pound force to move it and you push it one hundred feet then you have done, 10 x 100 or 1000 foot-pounds of work. But how long did it take you? What is the rate at which you work? This would be your power. Your POWER can be computed by the formula:

$$P = \frac{\text{work}}{\text{time}}$$

so if you took one minute to push the mower 100 ft., your power should be:

$$P = \frac{1000 \ (F \times D)}{1 \text{ minute}} \quad \text{or}$$

1000 foot-pounds per minute.

Your father may not be satisfied with the rate that you are doing the work, so he shows you how the job should be done by pushing the mower 100 ft. in only 30 seconds or one-half minute. His power would be:

$$P = \frac{1000 \ (F \times D)}{.5} \quad \text{or}$$

2000 foot-pounds per minute.

The same amount of work has been done, but due to your father's greater power, he accomplished or completed the work in less time.

You have heard of the term HORSEPOWER. When James Watt, the inventor of the steam engine, was looking for a suitable way to measure power, the horse was the common source of power. He compared the power of his engine to an ordinary horse. He might have used a dog or an oxen. If he had, we might be rating our automobiles today in oxen power or dog power. James Watt found that an average workhorse might work at the rate of 550 foot-pounds per second or 33,000 foot-pounds per minute. This rate of doing work is considered as one horsepower.

- Adjust furnace thermostats downward and replace or clean filters regularly.
- Install a low-flow showerhead and similar devices made for faucets.
- Reduce hot water temperature and usage. (This also reduces the possibility of burns.)
- Install a water heater insulation blanket to reduce water heating costs.
- When you're on vacation, reduce heating and air conditioning.
- Seal air leakage to attics, basements, and other unconditioned saces. Caulk around doors and windows.
- Seal leaks in hot water and steam pipes, and in heating and cooling ducts.
- Remove operating second refrigerators and freezers.
- Turn down waterbed heaters, insulate mattress and frame. An inexpensive time-clock can be used to prevent unnecessary daytime waterbed heater operation.
- Use lower wattage light bulbs. Switch to fluorescent bulbs. Screw-in fluorescent fixtures made it easy to switch.
- Connect incandescent lights to dimmer switches. Use timers for security lighting.
- Close fireplace damper when the fireplace is not in use.
- Wear warm clothing indoors in winter and light, loose fitting clothes in summer.
- Heat your house to no more than 68 degrees if health permits. Lower the temperature at night.
- In summer, set the air conditioning at a minimum of 78 degrees. Install awnings or stick-on window screening materials. Shade the air-conditioner's condensers, but do not restrict air flow. Plant deciduous trees and shrubs for shade.

Fig. 4-4. Tips to conserve electrical power. (Pacific Gas and Electric)

Electrical energy can be changed to mechanical energy. A motor is a good example of this conversion. Scientists have determined that one horsepower is equivalent to 746 watts of electrical power.

HOW TO CONSERVE ELECTRICAL POWER

Listed in Fig. 4-4 are some tips on how to conserve electrical power in the home. These suggestions cost little or nothing, yet if they are used they may save hundreds of dollars.

QUIZ — UNIT 4

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Power is equal to _____ × _____.
2. The rate at which energy is applied to a load of work is called _________.
3. Your house has a 110 volt electric circuit. How much current will a 1000 watt appliance use?
4. At 5 cents per kwh, how much will it cost to use the appliance in question 3 for two hours?
5. One horsepower equals _________ watts.
6. A kilowatt equals _________ watts.
7. A certain appliance uses two amperes of current when connected to a 100 volt source. What is the power?
8. What is the resistance of the appliance in question 7?
9. A certain appliance has a resistance of 100 ohms. At 100 volts how much current is used?
10. A meter used to measure energy consumed is called a _________.

On a separate sheet of paper, copy the PIRE wheel in Fig. 4-3. Work out the answers to the problems below using your PIRE wheel. Write your answers on a separate sheet of paper.

11. E = 100V, I = 2 amps., R = _______.
12. E = 50V, R = 1000 ohms, I = _____.
13. I = .5 amps., R = 50 ohms, E = ____.
14. E = 10V, I = .001 amps., R = _____.
15. I = .05 amps., R = 1000 ohms, E __.
16. P = 10W, I = 2 amps., E = _______.
17. E = 100V, I = .5 amps., P = _____.
18. P = 500V, E = 250V, I = _________.
19. I = .01 amps., R = 100 ohms, E =__.
20. P = 100W, 1 = 2 amps., R = _______.
21. E = 10V, P = 10W, R =___________.
22. E = 500V, I = 2 amps., R = _______.
23. E = 100V, R = 1000 ohms, P = ____.
24. I = .5 amps., R = 50 ohms, P = ____.
25. I = 4 amps., R = 10 ohms, P = ____.
26. I = 10 mA, E = 50V, P = _________.
27. I = 20 mA, E = 100W, R = _______.
28. P = 10W, I = 1 amp., R = _________.
29. E = 1000V, R = 1000 ohms, I = __.
30. I = 100 mA, R = 100 ohms, E = __.
31. I = 100 mA, R = 100 ohms, P = __.
32. P = 500W, E = 100V, I = _________.
33. E = 100V, R = 100 ohms, P = ____.
34. E = 50V, R = 10 kilohms, I = _____.
35. P = 10W, R = 10 ohms, E = _______.
36. P = 50W, R = 2 ohms, I = _________.
37. R = 100 ohms, P = 100W, E = _____.
38. I = .001 amps., R = 1 megohm, P =
39. E = 200V, I = 200 mA, P = _______.
40. E = 600V, I = 300 mA, P = _______.

Unit 5

SERIES CIRCUITS

After studying this unit, you will be able to answer these questions:

1. **How are electrical devices connected in series?**
2. **What are the laws of series circuits?**

Consider one of the highways between your hometown and a nearby community. While traveling along this one-way road, you must pass over four bridges. These bridges must have stretches of road between them, but they are connected together by means of the road. If you travel this road, you must pass over each bridge as you come to it. These bridges can be considered as being in SERIES with each other, Fig. 5-1.

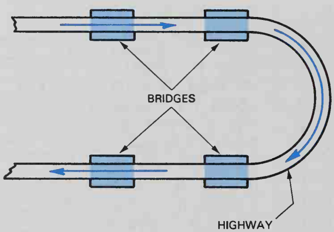


Fig. 5-1. The bridges on the highway are in series.

Before each bridge is a traffic sign, "Slow down, narrow bridge." You reduce your speed and the bridge slows down your progress.

You can compare this traffic situation to a simple electrical circuit, Fig. 5-2. The highway has been replaced by an electrical conductor or wire. The bridges have been replaced with resistors, R. Your travel in the direction of the arrows has been replaced by a flow of elec-

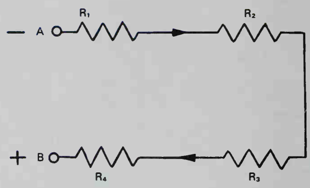


Fig. 5-2. The resistors are in series.

trons. R_1, R_2, R_3, and R_4 are all in series. Each R has a certain resistance to the flow of electrons from point A to B. The total resistance in the series circuit, then, is equal to the sum of all the resistors.

$$R_T = R_1 + R_2 + R_3 + R_4$$

and

$$R_T = \text{Total resistance}$$

As you study Fig. 5-2, you will observe that all electrons entering the circuit at point A, must flow through R_1, R_2, R_3, and R_4 before reaching point B. Also, all electrons going in at point A must come out at point B. None are lost along the way. So we conclude that the electron flow or current must be the same at any point in the circuit.

$$I_T = I_{R_1} = I_{R_2} = I_{R_3} = I_{R_4}$$

In Fig. 5-3, the circuit has been redrawn to include ammeters that mesure the flow of current.

Every meter will read the same, regardless of the value of any one of the resistances. Of course, if any resistor is changed in value, the total current in the circuit will change. Ohm's Law shows this to be true.

$$I = \frac{E}{R_T}$$

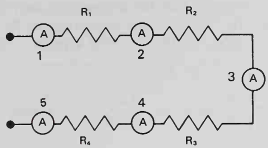


Fig. 5-3. All of the ammeters in the circuit will read the same.

VOLTAGE DROP

In our study of the volt, we learned that it was the unit of measurement for potential difference or electromotive force. A force is required to cause a current to flow through a circuit. In Fig. 5-4, the circuit has been redrawn and values assigned.

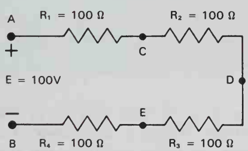


Fig. 5-4. The resistance and voltage are known. What are the voltage drops?

(Notice the Greek letter Ω which means ohms.)

The total resistance of this circuit would equal:

$$R_T = 100 + 100 + 100 + 100 = 400\ \Omega$$

The current flowing in all parts of the circuit would be:

$$I = \frac{100}{400} = .25 \text{ amps}$$

But point A has a potential of 100 volts and point B is zero. Somewhere along the circuit between A and B, the 100 volts has been lost.

You can understand how this can happen when you think of a resistance as something which must be overcome by a force. Actually the resistance has been overcome, but some of the force or voltage has been lost. The voltage lost by resistance in a circuit is called the VOLTAGE DROP or IR drop. It is called IR drop because Ohm's Law states that:

$$E \text{ voltage} = IR$$

To find the voltage drop for each resistor is easy. First find the current, which we have computed as .25 amps., then:

$$E_{R_1} = .25 \times 100 = 25V$$
$$E_{R_2} = .25 \times 100 = 25V$$
$$E_{R_3} = .25 \times 100 = 25V$$
$$E_{R_4} = .25 \times 100 = 25V$$

The voltage lost across R_1 is 25 volts, so the voltage at point C is 100-25 or 75V.

The voltage lost across R_2 is 25 volts, so the voltage at point C is 75-25 or 50V.

The voltage lost across R_3 is 25 volts, so the voltage at point E is 50-25 or 25V.

The voltage lost across R_4 is 25 volts, so the voltage at point B is 25-25 or 0 volts.

Add up all the voltage drops and they will total 100 volts which is the applied voltage of the circuit.

$$25 + 25 + 25 + 25 = 100 \text{ volts}$$

The sum of the voltage drops in a circuit must equal the applied voltage.

$$E_T = E_{R_1} + E_{R_2} + E_{R_3} + E_{R_4}$$

In Fig. 5-5, we know the current (.5 amps) and the total resistance, ($R_1 + R_2 + R_3$ or $50 + 150 + 200 = 400$), but we do not know the applied voltage. Ohm's Law states that:

$$E = IR \qquad \text{so,}$$
$$E = .5 \times 400 = 200V$$

The voltage drops can be easily found:

$$E_{R_1} - .5 \times 50 = 25V$$
$$E_{R_2} - .5 \times 150 = 75V$$
$$E_{R_3} - .5 \times 200 = \underline{100V}$$
$$200V$$

The sum of the voltage drops is 200 volts and

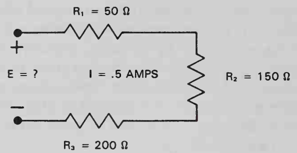


Fig. 5-5. The resistance and current are known. What is the value of the voltage?

is the same as we computed for the source voltage.

One more problem will show another way that a problem might be presented. In Fig. 5-6 we know the applied voltage (100V) and the voltage drops across the resistors, but we do not know the value of the resistors. The current is 100 mA or .1 amp.

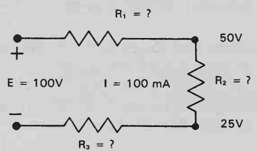


Fig. 5-6. The voltage drops and current are known. What are the values of the resistors?

According to Ohm's Law.

$$R = \frac{E}{I}$$

The voltage drop across R_1 is 50 volts, so,

$$R_1 = \frac{50}{.1} = 500\ \Omega$$

The voltage applied to R_2 is 25 volts, so,

$$R_2 = \frac{25}{.1} = 250\ \Omega$$

The voltage applied to R_3 is 25 volts, so,

$$R_3 = \frac{25}{.1} = 250\ \Omega$$

The problem can be proved by working it backwards. The total resistance equals $R_1 + R_2 + R_3$ or 500 + 250 + 250 equals 1000 Ω. Now,

$$I = \frac{E}{R} \text{ or } I = \frac{100}{1000} = .1 \text{ amp}$$

which proves that we did our calculations correctly.

There are thousands of applications of series circuits and voltage drops in radio and electrical circuits. You will be well advised to spend time on the practice problems.

Summary of the laws of a series circuit.

1. The total resistance in a series circuit is equal to the sum of all the individual resistors. ($R_T = R_1 + R_2 + R_3 \ldots$)
2. In a series circuit, the current flowing in all parts of the circuit is the same. ($I_T = I_{R_1} = I_{R_2} = I_{R_3} \ldots$)
3. The sum of the voltage drops in a series circuit is equal to the applied voltage. ($E_T = E_{R_1} + E_{R_2} + E_{R_3} \ldots$)

Now is a good time to look at the EXPERIMENTER, Project 1. In problem 3 of this experiment, the lights are connected in series. The lights, you will observe, burn much dimmer than the single light used in Problem 2.

Why is this so? The answer may be found in Ohm's Law. Each light is a resistance unit. When three lights are in series, consider the sum of the resistances. Increased resistance will decrease current flow.

QUIZ — UNIT 5

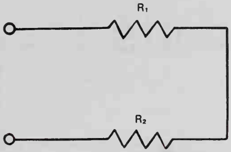
Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

In the following problems:

I = current
R = resistance in ohms
E = applied voltage
E_{R_1} = voltage drop across R_1

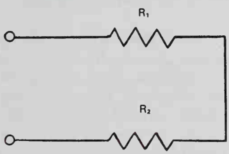
Solve for unknowns:

1.



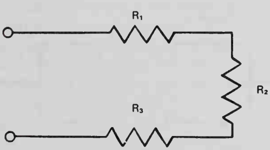
$E = 50V$	$R_T =$
$R_1 = 50\ \Omega$	$I =$
$R_2 = 150\ \Omega$	$E_{R_1} =$
	$E_{R_2} =$

2.



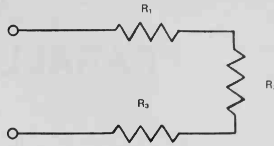
$E_{R_1} = 25V$	$E =$
$E_{R_2} = 175V$	$R_1 =$
$I = .5$ amp	$R_2 =$
	$R_T =$

3.



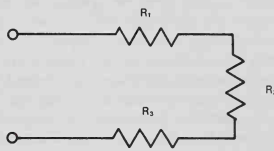
$R_1 = 100\ \Omega$	$E =$
$R_2 = 200\ \Omega$	$E_3 =$
$I = 2$ amps	$R_T =$
$E_{R_3} = 200V$	$E_{R_1} =$

4.

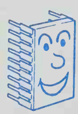


$E_{R_1} = 50V$	$E =$
$E_{R_2} = 150V$	$R_1 =$
$E_{R_3} = 200V$	$R_2 =$
$I = .25$ amp	$R_3 =$

5.



E_S = E supply	$E_{R_1} =$
$R_1 = 1000\ \Omega$	$E_S =$
$R_3 = 500\ \Omega$	$R_T =$
$E_{R_2} = 10V$	$E_{R_3} =$
$I_{R_1} = .001$ amp	$R_2 =$



CHIP SAYS:

"Never use a lamp or appliance cord in your home if the insulation covering is worn and ragged. Never remove a plug from an outlet by pulling on the cord. Always pull by the plug."

Unit 6

PARALLEL CIRCUITS

After studying this unit, you will be able to answer these questions:

1. **How are electrical components connected in parallel?**

2. **What are the laws of parallel circuits?**

When we were studying the series circuit, the example of the highway between two towns was used. We learned that the several bridges along that highway were in series and each bridge offered a definite amount of resistance to the flow of traffic. As more automobiles are used each day, the need exists to provide better and faster highways. Your state may be constructing new superhighways so more cars may travel safely without the resistance of narrow bridges and curves. The reason is apparent; more cars can travel on a new two-lane road than could travel on the old one-lane road. In fact, twice as many cars can travel on a double road.

If road A has the capacity of one hundred cars per minute and road B has a capacity of one hundred cars per minute, then roads A and B together have a capacity of 20 cars per minute, Fig. 6-1. The bridges on each road still may offer some resistance to the flow of automobiles.

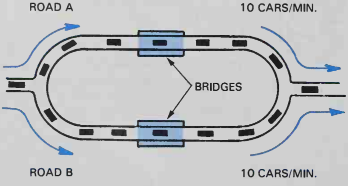


Fig. 6-1. The bridges are in parallel.

One could say that these roads are parallel to each other; that the bridge on road A is parallel to the bridge on road B. This same example can be applied to an electrical circuit. This example will help the beginning student in electricity to understand that in a PARALLEL CIRCUIT the resistance decreases because more paths are provided for the flow of electricity.

EQUAL RESISTORS IN PARALLEL

In Fig. 6-2, the highways have been replaced by an electrical circuit. R_1 and R_2 are the bridges or resistance. The automobiles are replaced by electrons flowing along their highways called conductors. At point X the electrons divide; part taking road A and the other part taking road B. At point Y the electons rejoin and continue on their way. Thus, a PARALLEL CIRCUIT has more than one path for current to flow. The parallel combination of resistance units offers less resistance to current flow than either single resistor.

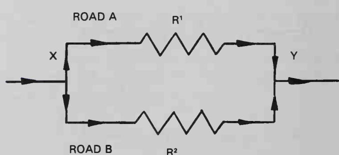


Fig. 6-2. The resistors are in parallel.

In Fig. 6-3, assume that R_1 equals 100 Ω and R_2 also equals 100 Ω. By combining the two in a parallel circuit, the total resistance of the circuit is only 50 Ω. The formula for finding the total resistance of a circuit (R_T) when the

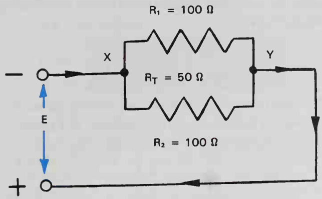


Fig. 6-3. Equal resistors in parallel.

resistors are in parallel and all equal is:

$$R_T = \frac{R}{N}$$

where,

R_T = total resistance

R = value of any one resistor

N = number of resistors

Apply this formula to Fig. 6-3 and you have,

$$R_T = \frac{100}{2} = 50\ \Omega$$

Like all circuits there is a voltage, E, across the input terminals which causes the electrons to flow in the circuit.

Let's draw some conclusions about this circuit.

1. The voltage across all branches or paths of a parallel circuit is the same. In this case it is the same as the applied voltage (E). You can see that the voltage across R_1 is the same as the voltage across R_2 since the ends of the resistors are connected to the common points X and Y or $E_T = E_{R_1} = E_{R_2} \ldots$
2. The total current in the circuit is equal to the sum of all the currents flowing in the branches of the parallel circuit or $I_T = I_{R_1} + I_{R_2} \ldots$

An example using actual values will help you understand this.

In Fig. 6-4, total resistance (R_T) of the circuit is:

$$R_T = \frac{R}{N} = \frac{200}{2} = 100\ \Omega$$

The current flowing in the circuit can be found by Ohm's Law:

$$I = \frac{E}{R} \text{ or } \frac{200V}{100\ \Omega} = 2 \text{ amps}$$

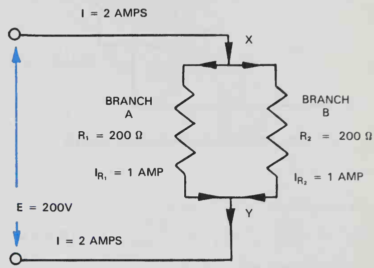


Fig. 6-4. The circuit current divides between the branches of parallel circuit.

When the current of 2 amperes reaches point X, it divides. One ampere flows around branch A through R_1, and one ampere flows around branch B through R_2. At point Y the two currents rejoin.

The total current I_T = 2 amps
Current in branch A = 1 amp
Current in branch B = 1 amp
I_T = 1 amp + 1 amp = 2 amps

UNEQUAL RESISTORS IN PARALLEL

So far we have assumed that R_1 equals R_2. This is not always so. Often they are unequal, and there is not an equal division of currents in the branches of the parallel circuit.

In Fig. 6-5, when the current reaches point X, it will still divide, but the greater amount of current will flow through the branch B, because branch B has less resistance than branch A.

To compute the total resistance of a parallel circuit having two unequal resistors is not too difficult.

$$R_T = \frac{R_1 \times R_2}{R_1 + R_2}$$

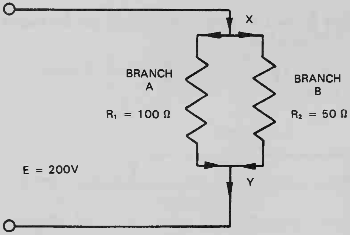


Fig. 6-5. Unequal resistors in parallel.

In our circuit:

$$R_T = \frac{100 \times 50}{100 + 50} = \frac{5000}{150} = 33.33\ \Omega$$

The total current I_T then:

$$I_T = \frac{200V}{33.33} = 6 \text{ amps}$$

To find how much current will flow in branch A:

$$I_A = \frac{200V}{100\ \Omega} = 2 \text{ amps}$$

and in branch B,

$$I_B = \frac{200V}{50\ \Omega} = 4 \text{ amps}$$

The sum of the branch currents $I_A + I_B$ equals 2 amps + 4 amps = 6 amps, which is the same as the total current flowing in the circuit.

CONDUCTANCE

The ability to conduct electricity is opposite the ability to resist the flow of electricity. So we could consider the current carrying ability of any wire or circuit either by stating its resistance to flow of electrons, or by its ability to conduct electrons. Its ability to conduct is called CONDUCTANCE. The letter symbol for conductance is G. Conductance is measured in SIEMENS. Conductance is the reciprocal of resistance. Do not let that term reciprocal frighten you. It simply means, one divided by the resistance. If the resistance of a circuit is 4 ohms, then its conductance is 1/4 siemens. If G equals .25 siemens, the R equals 4 ohms.

TWO OR MORE RESISTORS IN PARALLEL

When two or more unequal resistors are connected in parallel, the conductance method of finding R_T is:

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

This formula involves the use of fractions, but you should have no trouble with it. An example will show you how it works. See Fig. 6-6.

$$R_T = \frac{1}{\frac{1}{100} + \frac{1}{200} + \frac{1}{400}}$$

Find the least common denominator of the fraction, which is 400.

$$R_T = \frac{1}{\frac{4}{400} + \frac{2}{400} + \frac{1}{400}}$$

$$= \frac{1}{\frac{7}{400}}$$

now,

$$1 \div \frac{7}{400} \quad \text{is the same as}$$

$$1 \times \frac{400}{7} = \frac{400}{7} = 57.1\ \Omega$$

$$R_T = 57.1\ \Omega$$

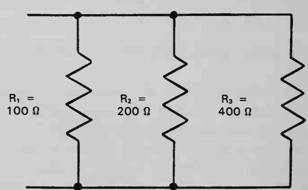


Fig. 6-6. Three unequal resistors in parallel.

Note: In all problems dealing with resistance in parallel circuits, the total resistance must always be less than the value of any resistor in the parallel circuit. Use this information to check your work.

EQUIVALENT RESISTANCE

The flow of electricity around a circuit depends upon resistance in the circuit. This

resistance may be a single resistor or several resistors connected in series or parallel. Regardless of how many resistors there are or how they are connected, they will combine together to give a total resistance in the circuit. The total resistance is the limiting factor which affects the current flow. In other words, the total of all resistances might be represented by one resistor only which the technician calls the EQUIVALENT RESISTANCE of the circuit. See Fig. 6-7.

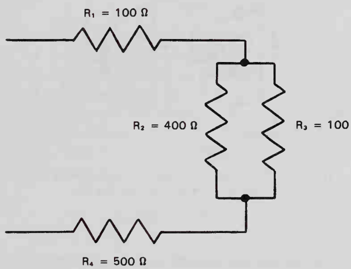


Fig. 6-7. A combination circuit of series and parallel resistors.

Step I. Combine R_2 and R_3

$$R_T\ (R_2 \text{ and } R_3) = \frac{400 \times 100}{400 + 100}$$

$$= \frac{40000}{500} = 80\ \Omega$$

The circuit will appear as in Fig. 6-8.

Step II. Combine the three resistors in Fig. 6-8. They are in series so,

$$R_1 + (R_2 \text{ and } R_3) + R_4 =$$

$$100 + 80 + 500 = 680\ \Omega$$

Electrically speaking, the circuits of Figs. 6-7, 6-8, and 6-9 are exactly the same. R_E (680 Ω) is the equivalent resistance of the combination of R_1, R_2, R_3, and R_4.

Before leaving the study of series and parallel circuits, let's look at some familiar applications.

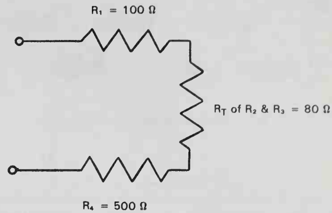


Fig. 6-8. Resistors R_2 and R_3 have been combined.

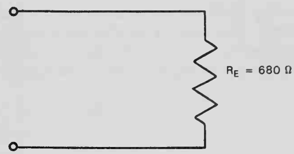


Fig. 6-9. The equivalent resistance of the series and parallel combination circuit.

A string of Christmas tree lights could be connected in either manner. Compare Figs. 6-10 and 6-11.

The symbol  is used for a light bulb.

In Fig. 6-10 the eight lights are connected in series. All of the electricity used flows through each light. If one light should burn out, all the lights would go out.

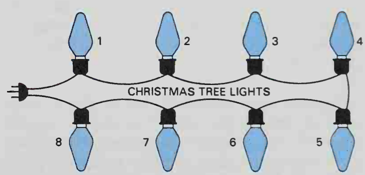


Fig. 6-10. Christmas tree lights in series.

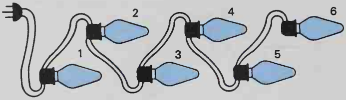


Fig. 6-11. Christmas tree lights in parallel.

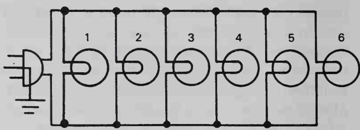


Fig. 6-13. Schematic drawing for Christmas tree lights connected in parallel.

Fig. 6-12 shows exactly the same circuit as in Fig. 6-10 except that conventional schematic symbols are used. This is the way you would find the circuit in the usual electrical drawing.

In Fig. 6-11 the same lights are connected in parallel. The current divides between the six branches of the circuit. If one light should burn out, the remaining five will still be lighted.

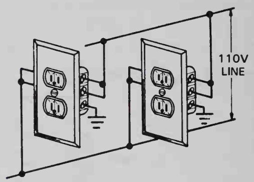


Fig. 6-14. Convenience outlets in your home are connected in parallel across the line.

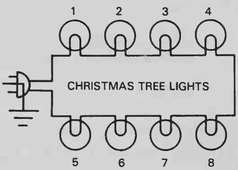


Fig. 6-12. Christmas tree lights in series using conventional schematic symbols.

Fig. 6-13 shows the schematic drawing for six Christmas tree lights connected in parallel.

The electrician, in wiring your home, wired all your lights, convenience outlets and appliances in parallel. We will apply our knowledge of parallel circuits and see what happens. See Fig. 6-14.

Here we have two convenience outlets wired parallel across the line. This is the typical method used to wire by electricians. No electric current is being used because no appliance or light has been plugged in. Note the ground which serves as a protection in case of a short.

When load or light R_1 is plugged in, a current will flow, Fig. 6-15:

$$I = \frac{110}{100} = 1.1 \text{ amps}$$

and the power is,

$$P = I \times E \quad \text{or}$$
$$P = 1.1 \times 110 = 121 \text{ watts}$$

R_1 (100 Ω) is the only resistance in the circuit.

When R_2 is plugged in, then R_1 and R_2 are in parallel and the total resistance is,

$$R_T = \frac{100}{2} = 50\ \Omega$$

and the current flowing is,

$$I = \frac{110}{50} = 2.2 \text{ amps}$$

The power is,

$$P = 2.2 \times 110 = 242 \text{ watts}$$

You can now see that as you plug in more appliances or lights the current increases and you use more watts and consequently your electric bill is higher. To burn lights unnecessarily is wasteful and expensive.

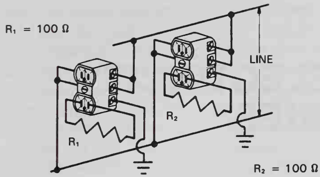


Fig. 6-15. Appliance plugged into convenience outlets are in parallel across the line.

Refer again to the EXPERIMENTER, Project 1, in the back of this book. In problem 4, the lights are connected in parallel. Each light burns at the same brilliance as the single light of problem 2. Because the circuit is a parallel circuit, each light decreases the total resistance of the circuit. The current, of course, will increase. (Ohm's Law.)

QUIZ — UNIT 6

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Write the formula for total resistance when all resistors in a parallel circuit are equal.

   R_T = ______________.

2. Write the formula for total resistance of two unequal resistors in parallel.

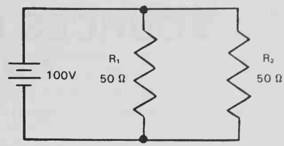
   R_T = ______________.

3. Write the formula for total resistance of three unequal resistors in parallel.

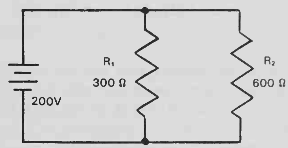
   R_T = ______________.

4. The sum of the branch currents in a parallel circuit is equal to the __________ of the circuit.
5. The voltage across all branches of a parallel circuit is ______________.
6. Conductance has the letter symbol _____ and is measured in _____. It is the _____ of resistance.
7. What is the conductance of a circuit that has ten ohms resistance ____________?

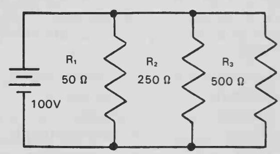
8. Find: R_T = ________ I_{R_1} = ________
   I = ________ I_{R_2} = ________



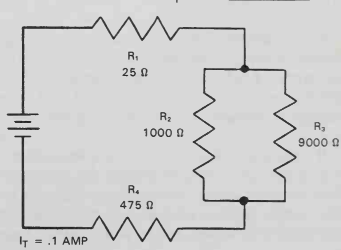
9. Find: R_T = ________ I_{R_1} = ________
   I = ________ I_{R_2} = ________



10. Find: R_T = ________ I_{R_2} = ________
    I = ________ I_{R_3} = ________
    I_{R_1} = ________



11. Find Equivalent: (R_E) = ________
    E_T = ________



Unit 7

SOURCES OF ELECTRICITY BATTERIES

After studying this unit, you will be able to answer these questions:

1. **What produces electricity?**
2. **How are batteries constructed and used?**

In previous lessons you learned about the unit of electrical pressure, the volt. This voltage is caused by a DIFFERENCE IN POTENTIAL between two points. This difference in potential was necessary to cause an electric current to flow through a circuit. In this unit we will discuss the methods of producing electricity.

SOURCES OF ELECTRICITY

There are six methods of producing a difference in potential or a voltage. These six methods are commonly known as SOURCES OF ELECTRICITY.

1. Chemical action — battery or cell
2. Magnetism — generator
3. Friction — static
4. Heat — thermocouple
5. Light — photocell or solar cell
6. Pressure — crystals

THE VOLTAIC CELL

In the middle of the eighteenth century, the Italian physicist Alessandro Volta conducted experiments which led to the discovery of the voltaic cell. The words voltaic and volt were named in memory of this great scientist.

If we should take a piece of zinc and suspend it in a glass dish filled with acid, we would find that the acid would chemically react with the zinc. Little bubbles of hydrogen gas would accompany this action, as the zinc is eaten away by the acid. Were we to test this piece of zinc, we would find that it had a negative charge. The instrument used to make this test is called an ELECTROSCOPE.

Now suspend a carbon rod in the same acid solution with the piece of zinc. A test of the carbon rod reveals that it is positively charged. A POTENTIAL DIFFERENCE has been created. If a wire were connected between the carbon rod and the zinc plate, a current would flow. It would continue to flow as long as there was chemical action.

In Fig. 7-1, the carbon and zinc elements are called ELECTODES and the acid solution is known as the ELECTROLYTE. Many different kinds of materials and acids have been used in experimental voltaic cells.

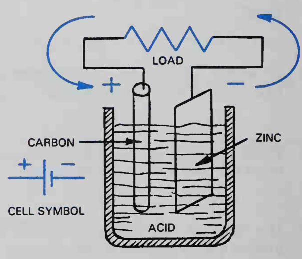


Fig. 7-1. A simple voltaic cell.

Two defects of such a cell should be considered. The zinc plate contains some particles of carbon. Coke and coal are used in the smeltering process of extracting the zinc from

the ore. These particles of carbon are released as the zinc is eaten away. They become positively charged in the same manner as the carbon electrode. They attach themselves to the zinc electrode and form small voltaic cells within the larger voltaic cell. These little cells contribute nothing to the energy which can be supplied by the cell. This internal chemical action creating worthless energy is called LOCAL ACTION.

The hydrogen bubbles that are formed when the zinc plate is placed in the acid are attached to the positive carbon electrode. These bubbles form a coating around the carbon and effectively insulate it from the chemical reaction. The voltage of the cell will drop, as a result of this undesirable action. The cell is said to be polarized. Various compounds are used in cells which unite with the free hydrogen and counteract this polarization.

DRY CELLS

The liquid voltaic cell has limited use today. Another version of the same cell is the dry cell. These are used extensively in flashlight and radio batteries. The dry cell consists of a zinc container, in the center of which is a suspended carbon rod. Study the construction shown in Fig. 7-2.

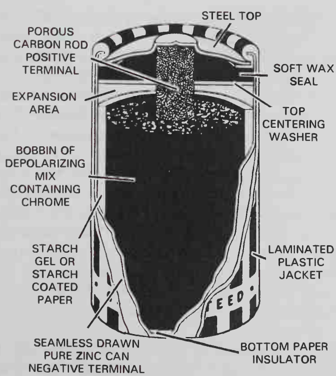


Fig. 7-2. A cut-away view of a dry cell. (Burgess Battery Co.)

The container is filled with a moist paste of manganese dioxide, carbon, and electroyte. The double chemical reaction during discharge of the cell produces free electrons which cause the zinc container to be the negative terminal and the center carbon electode will be positive.

A cell constructed in this manner creates a potential difference of about 1.5 volts. After the chemical action has been used up, the cell is dead. Such a cell is known as a PRIMARY CELL. A primary cell cannot be recharged.

MERCURY CELLS

Mercury cells are designed to provide high energy and stable voltage. They are used in electronic products ranging from watches to smoke alarms to cardiac pacemakers. Their high energy output permits extensive miniaturization of products that utilize these cells.

Mercury cells are available in sizes ranging from 0.005 to 3.0 cubic inches. The basic chemicals used in their production are a mercury oxide cathode and a zinc anode (compacted powders) and an alkaline electrolyte (liquid).

These cells are made in two general types:

1. Pure mercuric oxide.
2. Mercuric oxide with a small fraction of manganese dioxide.

The first type, at 1.35 volts, maintains extremely stable voltage over a considerable period of time. It is used as a voltage reference and in high reliability applications. The second type of mercury cell, at 1.40 volts, is used in general applications where the need for stable voltage is less critical.

Mercury cells come in three basic constructions:

1. Flat cells used in hearing aids and watches.
2. Cylindrical cells found in general use.
3. Wound anode cells that feature improved low temperature performance.

ALKALINE CELLS

Alkaline manganese cells are used to power a wide range of products where the voltage stability and high energy of the mercury system are not of prime importance. Alkaline cells are used in radios, recorders, cameras, and calculators, both in original equipment and in the replacement market.

The basic components of the alkaline system are a manganese dioxide cathode, a zinc anode and an alkaline electrolyte. As with mercury cells, the cathode and anode are compacted powders, while the electrolyte is a liquid. These components are sealed in a steel jacket with a plastic top. End caps and outer steel jackets complete the assembly.

Alkaline manganese cells are available in cylindrical and button shapes. The cylindrical cells are in common use in many consumer devices. The flat cells are used in products that require a compact power source.

NICKEL CADMIUM CELLS (NICAD CELLS)

A very popular type of rechargeable cell is the nickel cadmium cell. These cells are used on many type of cordless home appliances such as the electric tooth brush, carving knives, razors, radios, small power tools, and flashlights. They are provided with the necessary components for recharging the cells by plugging into the customary home power outlet. These cells have a low internal resistance and deliver high currents with little loss of terminal voltage.

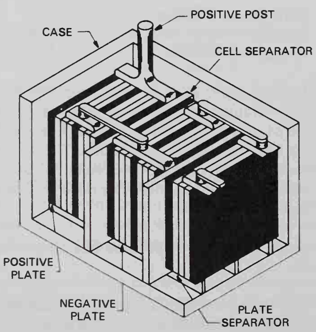


Fig. 7-3. The negative and positive plates are interlaced with separators between them.

Any description of the NICAD cell would be quite technical. However, the plates or electrodes are made by sintering (heating) powdered nickel into a nickel wire screen, which makes a strong and flexible plate. The positive plates are impregnated with nickel salt solutions. Cadmium salt solutions are used for the negative plates. The electrolyte is a solution of potassium hydroxide. The terminal voltage of the cell is about 1.33 volts.

THE STORAGE BATTERY

An improvement upon the voltaic cell is the lead-acid cell used in the storage battery. Such a battery is used in automobiles and for many other purposes. Actually a storage battery does not store up electricity. It would be more correct to say that it stores a chemical action which produces electricity. The lead-acid cell is said to be reversible, which means that it can be recharged and used over and over again. Such a cell is known as a SECONDARY CELL.

The plates or electrodes of the lead-acid cell are made of chemicals, which have been pressed into a grid-like frame. This frame acts as a rigid support and prevents the chemicals from falling apart. The negative plates are made of spongy lead, and are slate gray in color. The positive plates are made of lead peroxide and are brownish red in color. Each cell contains several of these thin plates. So that the maximum area of the plates may be used in the chemical action, the plates are interlaced, placing a positive plate between two negative plates. So that no plate will touch another plate, separators of wood, glass, or rubber are used. A thirteen plate cell would have seven negative and six positive plates, Fig. 7-3.

This assembly of plates and separators is placed in a hard rubber or glass case with necessary connections and terminals. Usually three or six cells are placed in one case. The

cells are filled with an electrolyte of sulphuric acid (H_2SO_4) and water. A cutaway view of a typical storage battery appears in Fig. 7-4.

Fig. 7-4. Cut-away of maintenance-free battery. (Delco Remy Div., General Motors Corp.)

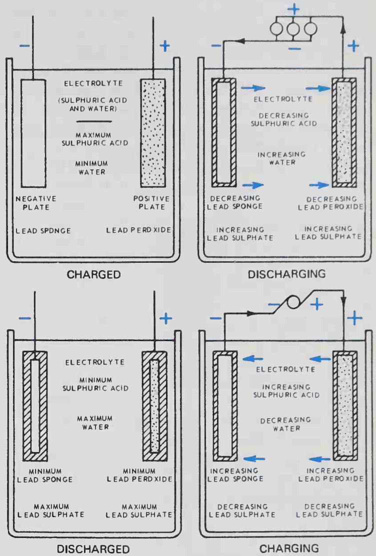


Fig. 7-5. The chemical action during charge and discharge is illustrated.

The chemical actions during charge and discharge are illustrated in the drawings in Fig. 7-5. Note, in particular, that during discharge the plates became increasingly lead sulphate and the electrolyte becomes nearer to water. During charge, the plates approach their original state and the electrolyte is richer with acid.

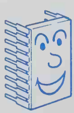
By reversing the flow of current through the battery by using a battery charger, illustrated in Fig. 7-6, or generator, the battery can be returned to its original state of charge.

An indication of the state of charge of a lead-acid cell is the amount of sulphuric acid in the electrolyte. All liquids have a specific weight in relation to an equal volume of water. This is known as the SPECIFIC GRAVITY of the liquid. The specific gravity of water is 1.000 and the specific gravity of sulphuric acid is 1.840. This means that sulphuric acid is 1.84 times heavier

Fig. 7-6. A battery charger such as used by garages and service stations.

than water. A fully charged lead-acid cell will have a specific gravity of about 1.300. As the battery discharges, the acid is used up and water replaces it. This specific gravity decreases to 1.150 to 1.100 for a fully discharged battery. The device used to measure the specific gravity of a liquid is called a HYDROMETER, Fig. 7-7.

Fig. 7-7. A hydrometer used to test the specific gravity or state of charge of a battery.



CHIP SAYS:

"1. It is dangerous to get battery acid on your hands or clothes. It will burn your hands and eat holes in your clothes. If you get acid on your hands, wash them immediately with clear water and then treat the burn with an approved ointment. Acid on your clothes may be neutralized by a solution of baking soda and water.
2. When batteries are charging, hydrogen gas is a product of the chemical action. It is explosive! Never bring an open flame or sparks near a charging battery. As an added precaution, always charge a battery in a well ventilated room. Never smoke in the area where a battery is being charged.
3. Lead-acid batteries are heavy. Do not strain yourself. Get help if necessary and use the proper carrying straps when you must move one."

CELL CONNECTIONS

We have used the term cell and battery in the previous discussions. Actually a single unit is a CELL. When several cells are connected together, they are known as a BATTERY. In practice, the term battery is used rather loosely, and usually means either a cell or a battery.

The terminal voltage of the lead-acid cell is about two volts. In order to get a voltage of six or twelve volts, such as required for an automotive battery, three or six cells respectively are connected together and placed in one container.

SERIES AND PARALLEL CONNECTIONS

When cells are connected in series, positive to negative, positive to negative and so on; the final voltage will equal the voltage of one cell times the number of cells.

$$E_{\text{one cell}} \times N = E_{\text{battery}}$$

Fig. 7-8 shows three 1.5 volt cells hooked up in series. The battery voltage is 4.5 volts.

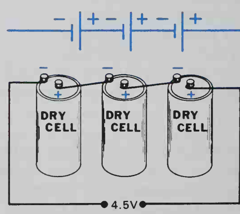


Fig. 7-8. Three cells connected in series.

When cells are hooked in parallel, positive to positive, positive to positive and so on, the final battery voltage will equal only the voltage of one cell. However, you will have a much stronger battery, and it will last much longer.

Fig. 7-9 shows three 1.5 volt cells hooked up in parallel.

The battery voltage is 1.5 volts. Various combinations may be connected to give desired voltages and capacities. The symbol for a battery in an electric circuit is:

BATTERY CAPACITY

The capacity of a battery is rated in AMPERE-HOURS. An automobile battery usually has a rating of 90 to 120 ampere-hours depending upon the number of plates in the battery, and its quality.

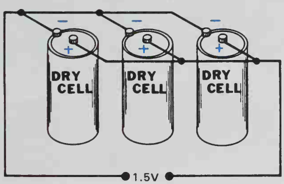


Fig. 7-9. Three cells connected in parallel.

A 100 ampere-hour battery theoretically will deliver,

1 amp for 100 hours
or
10 amps for 10 hours
or
any combination which will give a product of amperes × hours = 100

This capacity is determined under controlled laboratory conditions. If a battery is discharged rapidly, it will not deliver to its full capacity.

QUIZ — UNIT 7

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. A cell that cannot be recharged is called a __________ cell.
2. A cell which can be recharged is called a __________ cell.
3. In the lead-acid cell the negative plates are made of __________ and are __________ in color.
4. In the lead-acid cell the positive plates are made of __________ and are __________ in color.
5. The voltage of a lead-acid cell is __________ volts.
6. The dry cell has a __________ case, which is the __________ plate. The chemical used as the electrolyte is __________.
7. Two defects of the voltaic cell are ________ and ________.
8. Various cordless types of home appliances use __________ cells. These cells are __________ cells and can be __________.
9. Show in a diagram, the hookup required for six two-volt cells to produce a twelve volt battery.
10. Show in a diagram, the hookup of three two-volt cells as required to make a six-volt battery.
11. The specific gravity of a lead-acid cell is: When charged __________, when discharged __________.
12. The capacity of a battery is rated in ______.
13. What should you do if some battery acid spilled on your hands and clothes?
14. Why will a discharged lead-acid battery freeze in cold weather?
15. When the electrolyte in a lead-acid battery evaporates, it should be replaced by distilled water. Explain the reasons for this statement.
16. A newspaper advertisement states that a certain special battery has 15 plates and is rated 120 amp. hrs. What is the meaning of these specifications in terms of battery capacity?

Unit 8

SOURCES OF ELECTRICITY FRICTION, HEAT, LIGHT, PRESSURE

After studying this unit, you will be able to answer this question:
1. How friction, heat, light, and pressure can be converted to electrical energy?

The two major sources of electric power are the BATTERY and the GENERATOR using chemical action and magnetism to create electricity. However, friction, light, heat, and pressure have important applications with which we should become familiar.

VOLTAGE BY FRICTION

We learned in an early lesson that some atoms gave up their electrons when rubbed by a cloth. Remember the Greek "elektron?" Familiar examples of this phenomena are demonstrated in the laboratory by rubbing a glass rod with a silk cloth. The glass rod becomes positively charged. Rub a piece of vulcanite (hard rubber) with cat's fur and it becomes negatively charged. These charges are generally considered "electricity at rest" or STATIC CHARGES. However, the potential difference between the two can cause a flow of electric current. It is possible to build up very high static charges by means of friction.

The laboratory in your school may have a static machine, Fig. 8-1. A static machine produces an electric charge by mechanically rotating a specially treated glass disc. The charge is collected and stored in large capacitors or Leyden jars. When the charge is sufficiently large a miniature bolt of lightning or spark will jump across the gap between the ball-type electrodes. Caution: If you should use one of these machines, be sure to discharge the Leyden jars by bringing the two balls together, before you put it away. Someone could get an unhealthy shock due to your carelessness.

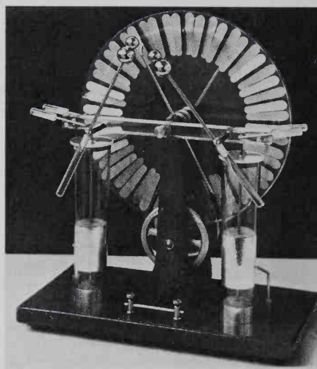


Fig. 8-1. A Wimshurst static machine. (Sargent-Welch Scientific Co.)

Another type of static machine is a Van de Graaff generator, Fig. 8-2. In this machine, an electric charge is carried up into the sphere on top by means of a motor driven, insulated belt. This charge is picked up from the belt and collected on the outside of the sphere. Large charges of static electricity may be generated with this machine. Large machines of this type will produce "artificial lightning."

The "Static Birds" which you made in Project 2 are an example of static electricity created by friction.

Lightning, one of the most destructive forces of nature, is a very convincing demonstration of electric charges. Rapidly moving air currents during a storm charge the clouds with static

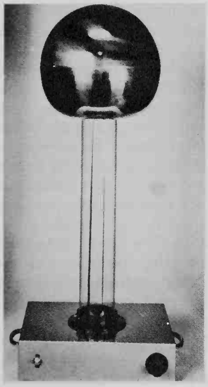


Fig. 8-2. A Van de Graaff generator. (Sargent-Welch Scientific Co.)

electricity. An enormous potential difference may be built up between two clouds, or between a cloud and the ground. When the charge is great enough, a great spark jumps across in the form of lightning, discharging the cloud.

VOLTAGE BY HEAT

If two dissimilar pieces of metal, such as an iron and copper wire are twisted together and heated in a flame, a potential difference or voltage will be developed across the ends of the wires. Such a device is known as a THERMOCOUPLE, Fig. 8-3. Although the voltage is very small, it can be used to indicate the temperature of the heat. Commercially made thermocouples are used extensively as heat indicating and control devices. A meter attached to the ends of the thermocouple responds to a change in voltage. The dial on the meter may be calibrated to read in degrees of heat.

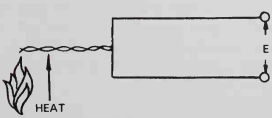


Fig. 8-3. A diagram of a simple thermocouple.

VOLTAGE BY PRESSURE

Certain natural crystalline substances such as quartz have unique properties. If a slab of crystalline quartz is placed between two metal plates and a pressure or vibration is applied, a voltage will be developed between the two plates, Fig. 8-4.

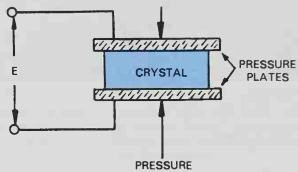


Fig. 8-4. Pressure exerted on the crystal by the contact plates creates a voltage.

This unusual property of a quartz crystal is called PIEZOELECTRIC effect. This was a very useful discovery. In the pickup arm of a stereo turntable, the vibrations caused by the needle running in the groove of the record are transferred to the crystal, which in turn converts the mechanical vibrations into a varying voltage. This voltage is amplified (made larger) to the strength necessary to operate a loudspeaker.

Crystals are also used in much the same manner in a crystal microphone. The sound waves from voice or music cause the plates to exert a pressure on the crystal which will convert this pressure into electrical energy. The voltage is amplified and used to operate a loudspeaker.

PHOTOELECTRIC EFFECT

Space vehicles and satellites use sun cells to provide the electrical energy to operate their equipment. A great deal of research has been completed to discover ways to convert the energy of the sun into useful power. The

Fig. 8-5. Small fan being powered by three photovoltaic cells producing 18 mA of current, enough to power several of the small fans, even without direct sunlight. (Honeywell, Inc.)

PHOTOVOLTAIC CELL is such a device. When light is directed on a photosensitive material such as selenium, electrons are set free and a voltage is generated across its terminals. The photocell is a useful device. It is used for such purposes as opening doors at a supermarket; it counts, grades, and sorts manufactured items on the production line. It is used in science, engineering, and medicine for all kinds of delicate counting and grading applications. A camera light meter may use a photocell, which indicates the correct camera setting for the light intensity. Photocells can be connected in series to generate a sufficient voltage to operate a radio or other devices. See Fig. 8-5.

Another popular light sensitive device (LSD) is the PHOTORESISTIVE CELL. This component changes its resistance under the influence of light intensity. A change of resistance in a circuit will also change the current in a circuit. The change in current may be indicated on a meter. A similar device may be used as a "light meter" by the photographer.

You will be interested to know that the photoelectric effect plays a major role at the television studio. In the television camera, the scene is focused upon a mosaic of many photoelectric cells, which convert the different shades and intensities of the picture into voltages. These voltages are used by the transmitter to send the picture.

QUIZ — UNIT 8

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Name six sources of electrical energy.
2. The property of a quartz crystal to generate a voltage when pressure is applied to it is called ________.
3. Two dissimilar metals may be joined together to measure temperature. This device is called a ________.
4. Name two common applications of quartz crystals in electric circuits.
5. List six ways that a photocell might be used.
6. The photosensitive material in the photocell is ________.

Unit 9
MAGNETISM

After studying this unit, you will be able to answer these questions:

1. **How an electric current can produce magnetism?**
2. **What are the common applications of the electromagnet?**

What is the great and mysterious force called magnetism? Like the study of the electron, scientists have learned how to use magnetism, and have proposed theories upon the nature of magnetism. Yet, no one has seen this mysterious force. You probably have a horseshoe magnet at home and have discovered that it will pick up nails and certain other kinds of metal. If you are interested in camping or scouting, you have used the compass and learned that it points in the general direction of North. The compass is one of our more common applications of magnetism.

Hundreds of years ago, the Greeks discovered small pieces of iron ore, called magnetite, would attract small pieces of iron. Because these small stones were found near Magnesia in Asia Minor, they were named magnetite. The word magnetism is derived from magnetite.

LODESTONES

Centuries ago, Chinese sailors used these small stones fastened to sticks or wood floating in a container of liquid. The stick or floating stone would turn in the direction of North and by this means the navigator could chart the direction the ship was sailing. This was the earliest form of a compass and these stones became known as "leading stones" or lodestones.

A material or metal that has the property of attracting metals such as iron and steel is known as a MAGNET. The materials which it will attract are called MAGNETIC MATERIALS. All magnets have two poles. The pole which is attracted toward North is called the NORTH POLE while the opposite pole is called the SOUTH POLE.

Between the north and south pole exists what the scientist calls a MAGNETIC FIELD consisting of many lines of magnetic force. This magnetic field is frequently referred to as the magnetic FLUX, Fig. 9-1.

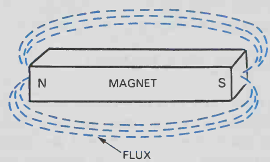


Fig. 9-1. A bar magnet showing magnetic flux.

Permanent type magnets are made in many shapes and sizes, Fig. 9-1. They all have the north and south poles. They all have magnetic fields. Materials used in the manufacture of such magnets have the ability to retain their magnetism over long periods of time. High carbon steel and special alloys, such as alnico, have exhibited this property. Low carbon steel and iron will not retain magnetism, but will serve the purpose of conducting or concentrating a magnetic field. You will be interested in how a magnet is made.

The molecular theory of magnetism explains this phenomena by stating that in an unmagnetized steel bar, the molecules are arranged in random order as in Fig. 9-2. When

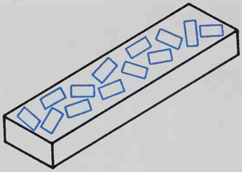


Fig. 9-2. In a nonmagnetized piece of steel the molecules are in random positions.

this magnet is rubbed with another magnet or placed in a strong magnetic field, all of the molecules line up like soldiers on the march. Each molecule assumes a north and a south pole, Fig. 9-3.

When the molecules are in this orderly formation, the steel is magnetized. This theory is proved to some extent by the fact that if the magnetized steel bar were broken into pieces, then each piece would be a magnet of its own.

THE EARTH AS A MAGNET

You may wish to try this experiment. Take a steel bar about two or three feet long. Hold it in a north-south direction and hit it several times with a hammer. The bar will become weakly magnetized and will attract a compass needle. Now turn the bar in an east-west direction and hit it several times again. A test with your compass will now show that it is demagnetized. This phenomena can be explained when you realize that the earth itself is one enormous magnet, and many invisible lines of magnetic force exist between the north and south pole, Fig. 9-4.

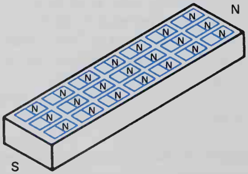


Fig. 9-3. The molecules are in line in a magnetized steel bar.

When you turned your bar in a north-south direction these magnetic lines of force flowed through your bar, because the bar had better permeability than the air about it. PERMEABILITY is the characteristic of a material to conduct magnetic lines of force. When you hit the bar, the molecules were jarred and lined up in magnetized positions.

Permeability, as the property of a material to conduct magnetism, can be compared to con-

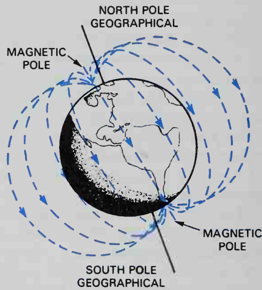


Fig. 9-4. The earth is a big magnet. A compass points toward the magnetic pole.

ductivity (G) in an electrical circuit. The resistance of a material to conduct magnetism is called RELUCTANCE and can be compared to resistance (R) in an electrical circuit.

LAWS OF MAGNETISM

Like the electron and the proton, the north and south poles of magnets show definite attraction for each other. LIKE MAGNETIC POLES REPEL EACH OTHER. The sketch in Fig. 9-5 shows this force in action. Notice the lines of force in each of the situations. The arrows indicate the direction of the forces, attraction, and repulsion. Carefully observe the polarity of the magnets.

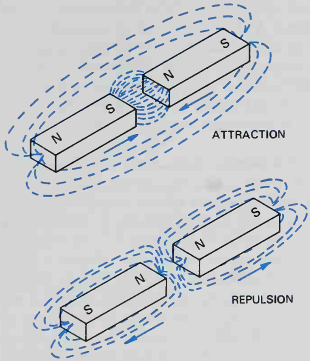


Fig. 9-5. Unlike poles attract. Like poles repel.

MAGNETIC FIELD PICTURES

It is hard to believe something that you cannot see. Let's take an ordinary bar magnet. Over this we will place a flat sheet of paper on which we have sprinkled some iron filings. By tapping the paper gently, the particles of iron will line themselves up in patterns conforming to the magnetic lines of force similar to Fig. 9-5.

THE SOLENOID

For many years scientists believed there was a definite relationship between electricity and magnetism. The experiments of Hans Christian Oersted in 1820 proved that a magnetic field was produced around a conductor when a current was flowing. You can prove this by performing the simple experiment shown in Fig. 9-6. Run a wire (insulated) through a piece of paper.

Place two or more small compasses on the paper close to the wire conductor. As the current flows, the magnetic field encircling the conductor will cause the compass needles to line up in the direction of the magnetic field. If you reverse the current by changing the battery terminals, the compass needles will indicate that the direction of the magnetic field has also reversed. To determine the direction of the magnetic field you can use the LEFT-HAND RULE. Grasp the conductor with your left hand, letting your thumb point in the direction of current flow. Your fingers around the conductor will point in the direction of the field.

Were you to wind a copper conductor into a coil of several turns, you will find that the fields around the wire combine to form a magnet, with one end of the coil north and the other south.

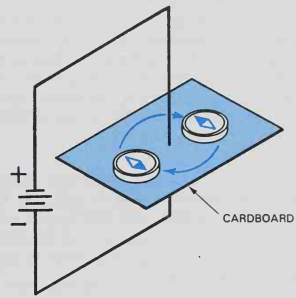


Fig. 9-6. Current flowing in a conductor creates a magnetic field around the conductor.

Such a coil is called a SOLENOID. The actual strength of the magnetism produced by such a coil depends upon the number of turns of wire and the current flowing through the coil. The product of the turns times the amperes is called the AMPERE-TURNS of the coil and is a measurement of the field strength of the coil.

THE ELECTROMAGNET

To improve the field strength of the solenoid, an iron core may be inserted. As iron provides a better path (higher permeability) for the lines of force than air, the strength of the magnetism is much greater, Fig. 9-7. Such a device is known as an ELECTROMAGNET and is used extensively in electronic equipment. You can use elec-

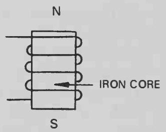


Fig. 9-7. An iron core increases the strength of electromagnet.

tromagnets in the construction of relays, doorbells, buzzers, and circuit breakers.

If the core, upon which the coil is wound, is made of iron or low carbon steel, the magnetic effect almost disappears when the current ceases to flow. Such magnetism remaining in the core is termed RESIDUAL magnetism. In order to use the coil as a controlled electromagnet, you would wind it on a core that retained little of its magnetism.

Another principle we should consider is the strength of the electromagnet. It depends, of course, upon the ampere-turns and the permeability of the core. Electromagnets can be made to operate devices requiring a tiny force, or one sufficient to move tons.

RELAYS

There are hundreds of applications of electromagnets in relays. A RELAY is a magnetic switch, and is usually used when it is necessary to control a rather large electric current by a small control current. See Fig. 9-8.

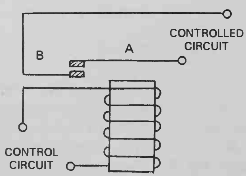


Fig. 9-8. A schematic diagram of a relay.

When you construct the MAGNETIC RELAY in Project 6, the principles of controlling circuits by electromagnetism will be understood. When a current flows in the control circuit, an electromagnet is produced which attracts armature A and closes the points, B, which is the switch in the heavy current circuit.

Another similar application is drawn in Fig. 9-9. Here the coil (C) is in series with the points (B). This is a kind of circuit protective device. As long as the current flowing in the circuit is within safe limits the magnetic force of coil (C) will not overcome the tension of spring (S). If the current exceeds a specified value, armature A will be pulled down and then points B will open thus breaking the circuit. The device is so arranged that points B must be manually closed before operation of the circuit can be resumed.

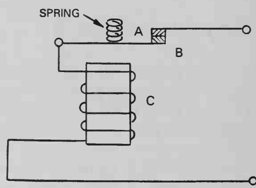


Fig. 9-9. A schematic diagram of a circuit breaker.

THE REED RELAY

The reed relay is another similar application of magnetism. Referring to Fig. 9-10, you will notice two magnetically sensitive switch contacts are enclosed in a glass tube. If a permanent magnet is brought close to the glass tube, it will cause the switch contacts to close. This type of relay is used in the OSCILLATING MOTOR (Project 9) in the project section.

The reed relay can also be operated by an electromagnet. The operating coil is placed around the reed relay. Your imagination will lead you to many unusual and fascinating applications of this device.

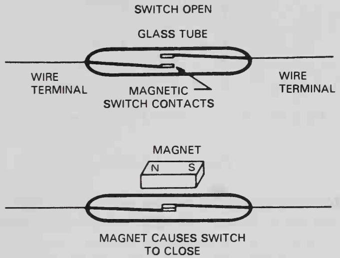


Fig. 9-10. A sketch of a reed relay. The magnet causes the reed contacts to close. This device is used in the WIG-WAG oscillating motor project in the project section of this book.

SOLENOID

Another interesting method of converting electricity to magnetism to mechanical motion is the solenoid, Fig. 9-11.

We have already learned that when a current flows through a coil, the coil becomes a magnet and has a north and south pole similar to the permanent bar magnet. This coil will attract particles of iron in much the same manner as a permanent magnet.

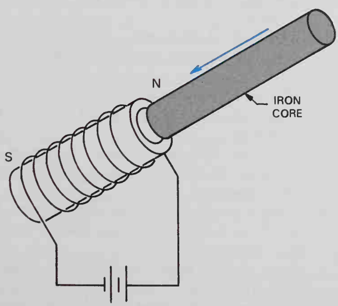


Fig. 9-11. The iron core is drawn into the coil.

If a core of soft iron is placed in the center of such a solenoid coil, it will be attracted by the coil, Fig. 9-11, and will be drawn into the center of the coil. It will actually pull the iron core into the coil. Its movement will stop when the attracting forces of each end of the coil are balanced, Fig. 9-12, and the core has centered itself in the coil, where the magnetic fields are the strongest.

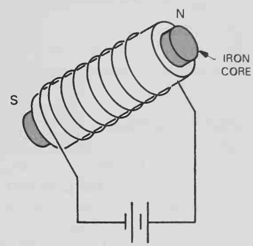


Fig. 9-12. The movement of the core stops when the magnetic forces are balanced.

This type of device has many applications. The movement of the iron core can be mechanically linked to switches, levers or gears to produce the desired action. One common application is used in the automobile, where the solenoid is used to mesh the gear on the starting motor with the gear on the flywheel of the engine. At the same time the solenoid action closes a switch which supplies current to the starting motor, Fig. 9-13.

The DOOR CHIME, Project 5 and the ELECTRIC ENGINE, Project 11 in the project section are based on the principles of the solenoid. You will find them interesting and practical applications of magnetism.

MAGNETISM BY INDUCTION

Why will a magnet pick up a nail? Experimentation has disclosed that if a piece of metal, such as a nail, is brought close to a magnet, it also becomes a magnet, assuming a polarity

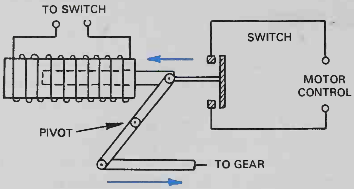


Fig. 9-13. The solenoid is used to close the motor switch and to engage the gears in the automotive starter.

that will cause attraction between the nail and the magnet. If a second nail is brought close to the end of the first nail, it also will be attracted. This is magnetism by INDUCTION which is the basis of the theory of magnetism, Fig. 9-14.

MAGNETIC SHIELDING

Closely related to this phenomena of magnetism by induction is the problem of keeping a magnetic field away from delicate testing instruments and meters. There is no known shield against magnetism. It passes through nonmagnetic materials as if they were not there. Try holding a piece of glass between a magnet and a nail. You will see that the nail is picked up in the same manner as if the glass were not there.

However, magnetism can be led around or directed away from instruments or devices needing protection. By placing a magnetic material such as a piece of iron in the field of a magnet, the flux lines of magnetism follow the direction of the iron, because the iron has a greater permeability than the surrounding air. The magnetic field has actually become a little stronger by this increased permeability. The field has been made to follow the iron and thus contain it.

Meters, transformers, and other components are frequently placed in cans which effectively shield them against the influence of magnetism. In radio equipment, metal fences or partitions are sometimes placed between sections of a circuit to prevent interaction between the circuits. In television equipment, shielding is also important to assure the best operating results.

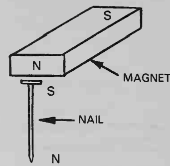


Fig. 9-14. The nail becomes a magnet by induction.

QUIZ – UNIT 9

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. A substance which has the ability to attract certain kinds of ferrous metals is known as a _________.
2. The magnetic field, consisting of many lines of magnetic force, running from the north pole to the south pole of a magnet is called the _________.
3. Draw two sketches showing the position of the molecules in an unmagnetized and a magnetized piece of steel _________.
4. If a magnetized bar of steel were broken into three pieces, what effect would it have on the magnetism of pieces of the steel bar _________.
5. The property of a substance to conduct a magnetic field is called _________.
6. The resistance a material has to conducting a magnetic field is called _________.
7. The north pole _________ the south pole.
8. Like poles _________ each other.
9. The strength of the magnetic force of a coil depends upon _________, and the product of these is called the _________ of the coil.
10. Why will a solenoid coil increase its magnetic strength when an iron core is inserted?
11. Why will a magnet pick up a nail?
12. What is the purpose of magnetic shielding?
13. A coil of 500 turns has a current of 2 amperes flowing through it. What is its field strength?
14. Draw a sketch of two bar magnets with N and S poles together. Draw lines showing the magnetic fields.
15. Draw another sketch of two bar magnets with the N pole of one near the N pole of the other. Draw lines showing magnetic fields.

Unit 10
MOTORS

After studying this unit, you will be able to answer these questions:

1. **How can electrical energy be converted into mechanical energy?**
2. **What is the theory and operation of the electric motor?**

In your lessons on magnetism you learned that unlike poles of magnets are attracted to each other, but like poles repel each other. In the case of relays and sucking coils, you observed that this attractive force of magnetism can be converted into mechanical action.

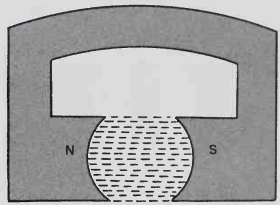


Fig. 10-1. A horseshoe magnet and magnetic field.

HOW THE MOTOR WORKS

The ELECTRIC MOTOR is the most common method of converting electrical energy into rotating motion. Motors are used in thousands of ways in home and industry. They are used to heat and cool the home, to keep food cold, to wash clothes, mix food, and to ventilate the home. They are used in industry to provide power for cutting, shaping, and finishing materials into useful products. Our life would be a hard life and our standards of living would be much lower, if the electric motor were not yet created by science and invention.

All motors operate on the principle of attraction and repulsion of magnetic poles. To understand this we will build a simple direct-current motor and trace each step of its construction to discover the method of producing rotation by the interaction of magnetic fields.

First, we must create a magnetic field, Fig. 10-1. The familiar horseshoe magnet produces the field, with lines of magnetic force running from north to south. This is known as a FIELD MAGNET.

In our study of electromagnets we learned that if a coil is wound on an iron coil, a magnet would be produced. The polarity of the electromagnet would depend upon the direction of current flow in the windings. We will wind such a coil and also put it on a round shaft, about which it can rotate, Fig. 10-2.

Assume that the current flowing will create the polarity as indicated in the drawing. This assembly is called the ARMATURE.

In Fig. 10-3, the field magnets and the armature have been combined into one assembly.

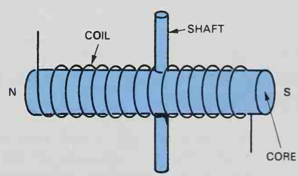


Fig. 10-2. An electromagnet is wound and placed on a shaft so that it will revolve.

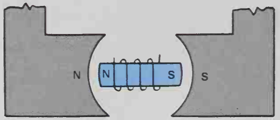


Fig. 10-3. The current flowing in the armature produces the indicated polarity.

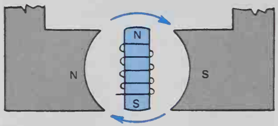


Fig. 10-4. North repels north and south repels south.

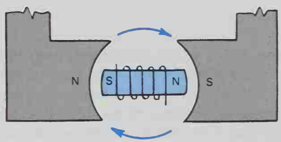


Fig. 10-5. South attracts north and north attracts south.

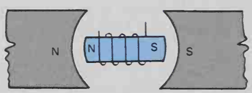


Fig. 10-6. The armature has rotated one-half revolution. At this point the current in the armature is reversed. Armature will continue to rotate.

Carefully notice the polarity of both the field and armature magnets.

Now a north pole will repel a north pole and a south pole will repel a south pole, so the armature will turn one quarter turn to the position shown in Fig. 10-4. The arrows indicate the direction of rotation.

But, north and south poles attract each other, so the armature is caused to turn another quarter turn and will come to rest in the position shown in Fig. 10-5.

No further rotation would take place. Remember that the polarity of the armature depended upon the direction of current flow.

Just as the north and south poles are lined up, change the direction of current flow in the armature by means of a switch. Then the situation would suddenly appear as in Fig. 10-6.

Is this position the same as when we started in Fig. 10-3? It surely is. So the like poles repel each other for a quarter turn and then the unlike poles attract each other for the final quarter turn. One complete revolution of the armature has been accomplished. By reversing the current in the armature again the rotation would continue. As long as the current was reversed each one-half revolution, the rotation would continue indefinitely. Fig. 10-7 shows graphically the chain of events just described.

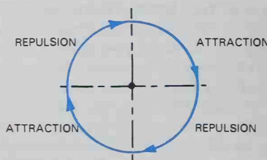


Fig. 10-7. This circle describes the chain of events during one complete revolution of the armature.

THE COMMUTATOR

It is necessary to change the direction of current flow in the armature at just the correct point to produce the continuing rotation. Of course we could not do this by hand with a switch. Some mechanical means is necessary and the device used to change the current in the armature is called a COMMUTATOR. Let's see how it works. Carefully study the following description of the operation of a commutator.

In Fig. 10-8 the ends of the armature coil are brought out to two pieces of metal, which are insulated from each other. Sliding on these metal sections are two spring metal contacts known as BRUSHES. A battery is connected to the brushes and arrows indicate the direction of current flow.

Current flows from battery to the brush (X), to commutator bar A, into the armature coil and out to commutator bar B, then through the brush (Z) to the battery.

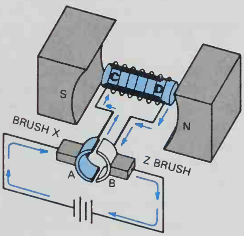


Fig. 10-8. The indicated current flow makes end C of the armature a south pole.

Such current will make (C) of the armature a south pole and D a north pole. The repulsion and attractive force causes the armature to rotate one-half turn. The commutator bars, of course, turn with the armature and the position of the armature after the half turn would appear as in Fig. 10-9. Now the current flows from the battery to brush (X) to commutator bar B, into the armature coil and out through commutator bar A, through the brush Z back to the battery. Such a current will make C of the armature a north pole and D a south pole. In other words, the commutator has changed the direction of current flow through the armature. This occurs each half revolution and the conditions for continued rotation have been satisfied. If you did not understand this the first time you read it, follow the action through step-by-step until you have a clear picture in your mind of the underlying principles of electric motor operation.

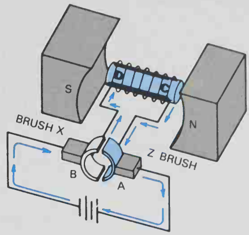


Fig. 10-9. After one-half revolution, end D becomes a south pole.

MOTOR CIRCUITS

In the explanations that follow, the diagram in Fig. 10-10 will be used to designate a motor. The various parts are named.

To improve the rotating force of the simple motor, it is possible to wind coils around the field magnets and make them strong electromagnets. Such windings are known as FIELD WINDINGS. An example of a SERIES type of DC motor appears in Fig. 10-11. In the series motor all of the current flows through the armature windings and the field windings. Such a motor varies its speed according to the load it must turn. It has the ability to start under heavy loads. The automobile starting motor is a series type motor.

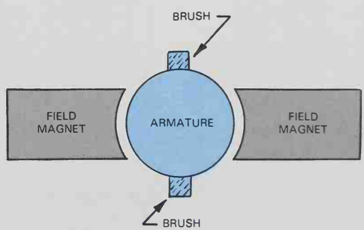


Fig. 10-10. A diagram showing the major parts of a motor.

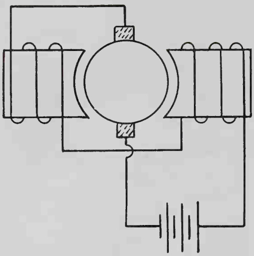


Fig. 10-11. The diagram of a series wound motor.

A second type of motor is the SHUNT or parallel wired motor, Fig. 10-12. In the shunt motor, the current divides. Part flows through the armature windings and the remainder through the field windings. Such a motor tends to keep a constant speed under varying load conditions. It is very well suited to the operation of machine tools in a school or home workshop.

There are other types of motors using both series and shunt windings that are known as COMPOUND motors. Detailed information about all of these DC motors can be found in textbooks on advanced electricity.

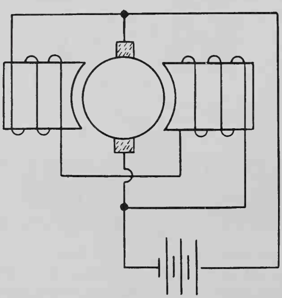


Fig. 10-12. The diagram of a shunt or parallel wound motor.

Further improvements are made upon our simple motor for commercial use. In studying the sequence of events as a motor completes one revolution, you will readily see that the turning force created by the interacting fields could be greatly improved if more field and more armature poles were used. The repulsive and attractive forces of magnetic fields decrease rapidly as the distance between them is increased. Mathematically speaking, the magnetic force between two poles varies inversely as the square of the distance between them. So by using more poles in a motor, the distance between poles is decreased and as a result the turning force is increased.

THE COMPLETE MOTOR

The field windings are wound on the field poles and the armature and commutator are mounted on a shaft. The whole assembly is placed in a shell or case. Suitable bearings are provided for the armature shaft. The case is provided with a means of holding the brushes under spring tension, so that they will constantly ride on the commutator bars. As the bars and brushes wear, the springs keep a constant brush pressure and assure a good electrical contact. Many motors have built-in fans, which circulate air through the motor, thereby keeping the motor cool during operation.

Project 10 describes in detail the construction of an experimental TWO-POLE MOTOR. This motor may be connected either as a series or a shunt wound motor. Study the action of the motor. Observe the function of the commutator.

MOTOR PRINCIPLES

The simple two-pole motor described in this text and constructed in Project 10 is frequently called the St. Louis motor. Although this motor depends upon the interaction between the magnetic fields of the armature and the field windings, a more accurate description of the modern motor must include the action of a current carrying conductor in a magnetic field.

Reviewing Unit 9 on Magnetism, you will recall that a magnetic field will exist around a conductor carrying an electric current. The left-

Fig. 10-13. Symbols used to show current flow and magnetic field.

hand rule states, that if you grasp the wire by your left hand with your thumb pointing in the direction of current flow, your fingers around the wire will indicate the direction of the magnetic field. Symbols currently used to represent this phenomena are shown in Fig. 10-13. The dot in the center of the circle indicates the point of an arrow. The current is flowing toward you. The cross in the circle represents the feathers on the arrow as it goes away from you or into the paper. The circular arrows indicate the direction of the magnetic field in each instance.

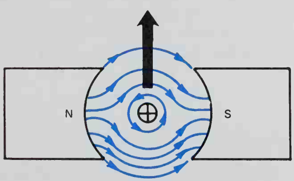


Fig. 10-14. The interaction between a magnetic field and a current carrying conductor.

When such a current carrying conductor is in another magnetic field, there will be interaction between the fields which will cause motion. Observe this action in Fig. 10-14. The arrows show the direction of both the permanent magnet field and the field around the conductor. On the upper side, the conductor field opposes the permanent field (arrows in opposite directions). On the lower side, the conductor field reinforces the permanent field (arrows in same direction). The conductor will move toward the weakened field or up.

Coils of wire or conductors are used in the armature of a motor. The MOTOR ACTION between the two fields causes the rotation. In the dc motor, of course, the current is periodically reversed by means of a commutator to provide continuous rotation.

QUIZ – UNIT 10

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. The rotating coils of the motor are called the ________.
2. A device to reverse the current flow in the armature windings is the ________.
3. Draw a diagram of a series motor.
4. List two characteristics of the series motor.
5. Draw a diagram of a shunt motor.
6. List two characteristics of the shunt motor.
7. Sliding contacts used to transfer electricity to armature are called ________.
8. List twelve devices or pieces of equipment that use electric motors.

Unit 11

METERS, READING A METER

After studying this unit, you will be able to answer these questions:

1. **What are the instruments used for measurement of values in an electric circuit?**

2. **What are the types and construction of meters?**

3. **How are meters connected in a circuit?**

There are many types and kinds of meters used in electrical work. A meter can be considered as an indicating device for determining electrical quantities.

The three most widely used meters are:

1. VOLTMETER: Used for measuring electrical pressure or force in volts (connected in parallel).

2. AMMETER: Used for the measurement of current flow in a circuit (connected in series).

3. OHMMETER: Used for the measurement of resistance of a circuit in ohms.

Sometimes these three meters are combined in one case and called a MULTIMETER. The technician may use the meter for measuring volts, ohms, or amperes, by turning a selector switch to the proper scale.

Other special purpose meters measure watts, watt-hours, frequency, capacitance, inductance, and other characteristics of circuits. Meters indicate on either digital readouts or calibrated scales the value of the measured electrical quantity. See Figs. 11-1 and 11-2. The accuracy of measurement is dependent upon the skill of the technician and the quality of the instrument. Manufacturers of measuring instruments calibrate their meters against standards supplied by our National Bureau of Standards.

D'ARSONVAL METER

The basic movement used in electrical measuring devices consists of a fixed permanent magnet and a moving coil. Such a device was used by the French physicist D'Arsonval in 1890.

The meter depends upon the interaction between a fixed magnetic field and a varying field. A coil of wire is suspended so it can turn within a fixed magnetic field. A current flowing through the coil in the proper direction will create a magnetic polarity which will interact with the fixed field and cause the moving coil to rotate. The amount of rotation is limited by hair springs. These springs also return the movable

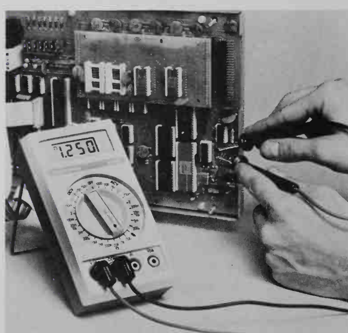


Fig. 11-1. Modern digital meter. (Beckman Instruments, Inc.)

Fig. 11-2. Volt-ohm-milliammeter.
(VIZ Mfg. Co.)

coil to its original position when the coil is not magnetized. A pointer or indicating device may be fastened to the moving coil.

The rotation of the coil causes deflection of the pointer along a dial or scale, which is calibrated in units of measurement. The force which causes the coil to move is proportional to the strength of the fixed magnetic field and the magnetic field of the coil. Of course the fixed field remains constant, but the moving coil field is dependent upon the current flowing through the coil. The larger the current, the greater rotation and deflection of the pointer. Fig. 11-3 is a phantom view of a simplified D'Arsonval meter movement.

IRON-VANE METER

A second type of indicating device is the IRON-VANE METER. In this instrument a fixed and a movable iron vane are suspended within

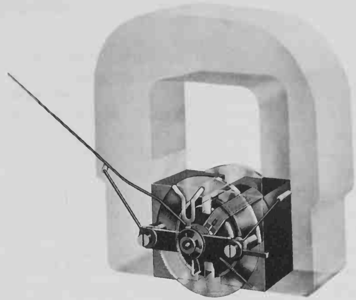


Fig. 11-3. D'Arsonval meter movement.

a solenoid coil. A pointer is attached to the moving vane. When a current flows in the coil, the two vanes become magnetized to the same polarity. As like poles repel each other the moving vane rotates away from the fixed vane. The force causing the movement is proportional to the magnetic field of the solenoid, which depends upon the current flowing through the coil. The deflection of the moving vane is limited by the force of a calibrated hair spring. Iron vane meters can be made to measure current or voltage. A simplified sketch of this type instrument is shown in Fig. 11-4.

METER SHUNTS

If a meter is designed to measure amperes, it is called an AMMETER. If it measures

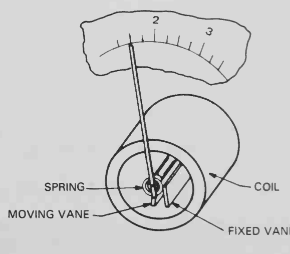


Fig. 11-4. A sketch of the iron-vane meter movement.

milliamperes, it then becomes a MILLIAMMETER. A combination meter which reads either in milliamperes or amperes can be made by switching precision SHUNT resistors across the meter terminals. If the resistance of the moving coil is known and the current required for full scale deflection of the meter, the shunts necessary to convert the meter to read in another range can quite readily be calculated. Consider the following examples: A milliammeter has a scale which requires one milliampere (.001 amp) for full scale deflection of the pointer. The internal resistance of the moving coil in the meter is 25 ohms. The voltage required for full scale reading of this meter would be:

$$E = I \times R$$

or

$$E = .001 \times 25 = .025 \text{ volts}$$

If we wished to have the meter read from 0-10 mA, it would be necessary to connect in parallel with the meter, a resistor shunt which would carry nine-tenths of the current (.009 amp) leaving the remaining one-tenth or .001 amp for the meter. Fig. 11-5 shows this circuit.

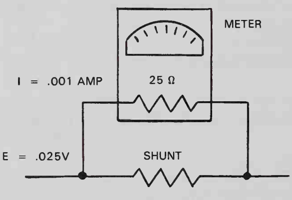


Fig. 11-5. The shunt resistor carries nine-tenths of the current.

The shunt resistance may be found by:

$$R = \frac{E}{I} = \frac{.025}{.009} = 2.78 \text{ ohms}$$

When this shunt is used, the meter will read from 0-10 mA rather than 0-1 mA. A reading of .8 for instance, would mean 8 mA.

The range of the meter may be further increased to read 0-100 mA. In this case, .001 amp flows through the meter and .099 amperes must flow through a shunt and the shunt resistance would be:

$$R_{shunt} = \frac{.025}{.099} = .253 \text{ ohms.}$$

A circuit incorporating all three ranges is shown in Fig. 11-6.

Switch Position	Scale
1	0-1 mA
2	0-10 mA
3	0-100 mA

Using the third scale, a .8 meter reading would indicate a current of 80 mA.

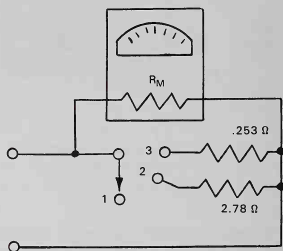


Fig. 11-6. A meter may have several ranges by adding shunt resistors to the circuit.

MULTIPLIERS

When the meter is used as a voltmeter the range can be extended by SERIES MULTIPLIER resistors. Using our previous example, we wish the meter to read 0-1 volt. As a current of .001 amps is required for full scale deflection, the total resistance in the circuit must be:

$$R_T = \frac{1}{.001} = 1000 \ \Omega$$

As the resistance of the meter is 25 Ω, then the series resistor must equal 1000 − 25 = 975 Ω.

To increase the range to read 0-100 volts, then:

$$R_T = \frac{100}{.001} = 100000\ \Omega$$

and series resistor equals,

$$100{,}000 - 25 = 99975\ \Omega$$

The diagram of this circuit with switching arrangement appears in Fig. 11-7.

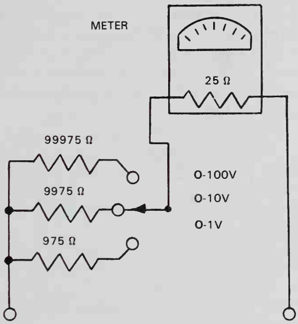


Fig. 11-7. The range of the voltmeter may be increased by adding multiplier resistors in the circuit.

In the multimeter, both the series multipliers and the shunts are connected to the basic meter by means of a switching arrangement, and the meter can be used to measure either voltage or current.

THE OHMMETER

In order to measure resistance with a meter, a variable resistor, (R_1), a voltage source and the unknown resistor (R_X) are connected in series with the meter, as shown in Fig. 11-8.

Continuing with our same meter, the movement requires .001 amps for full scale deflection. By using two flashlight batteries as a voltage source, the total resistance of the circuit would be:

$$R_T = \frac{3}{.001} \text{ or } 3000\ \Omega$$

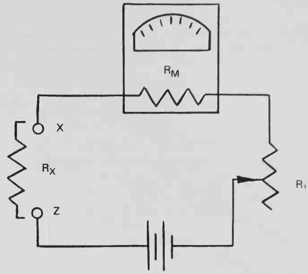


Fig. 11-8. Schematic diagram of a series ohmmeter.

In other words:

$$R_m + R_1 = 3000\ \Omega$$

R_1 is usually a variable resistor to compensate for the gradual changes in battery voltage due to age.

In order to use the meter, the terminals X and Z are shorted together and R_1 is adjusted to read zero resistance at full scale deflection. Then an unknown resistance can be inserted between X and Z terminals and its resistance read on a special calibrated scale of the meter. When points X and Z are open, the pointer does not deflect, and indicates infinite resistance on the scale.

You may wish to study other types of ohmmeters, including the shunt type meter.

METER CONNECTIONS

When measuring the current in a circuit, the ammeter must be inserted in series with the circuit. The circuit must be broken in order to connect the meter, Fig. 11-9.

When measuring voltage the meter is connected in parallel or across the circuit, Fig. 11-10.

METER PRECAUTIONS

1. A meter is a delicate precision instrument. DO NOT DROP it or treat it roughly.

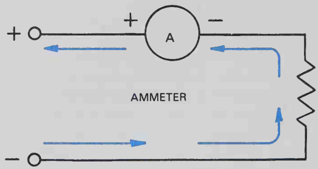


Fig. 11-9. The ammeter is connected in series to measure current.

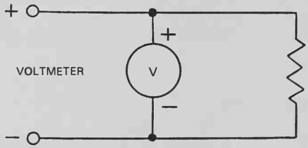


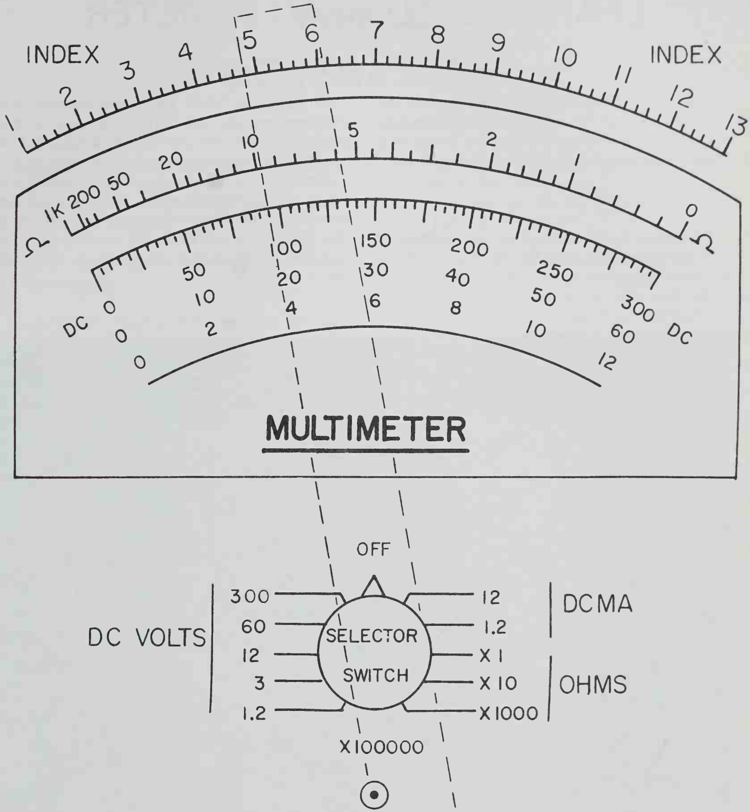
Fig. 11-10. The voltmeter is connected in parallel to measure voltage.

2. When connecting a meter, be sure to observe the proper polarity. NEGATIVE TO NEGATIVE. POSITIVE TO POSITIVE.
3. When making unknown measurements ALWAYS START WITH THE HIGHEST RANGE ON THE METER. If you tried to measure 100 volts on the one volt range, the meter would be destroyed.
4. DO NOT ATTEMPT TO MEASURE RESISTANCE IN A CIRCUIT, IF THE CIRCUIT IS "ALIVE" with power turned on.
5. Be sure all switches are correctly set for range and type of measurement to be made. See Figs. 11-1 and 11-2.

QUIZ — UNIT 11

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Draw the diagram for an ammeter with three ranges of current measurement.
2. If this meter required .001 amp for full scale deflection and the resistance of the meter coil was 100 ohms, compute shunt resistors for:
   0-10 mA range ________
   0-100 mA range ________
3. Draw diagram for a voltmeter with three ranges.
4. Compute series multiplier resistors: R_m = 100 Ω
   0-1 volt range ________
   0-10 volt range ________
   0-100 volt range ________
5. Draw the circuit for a simple series ohmmeter.
6. The two types of meter movements we have studied are the ________ and the ________ type meter.
7. Ammeters are connected in ________ with the circuit and voltmeters are connected in ________ with a circuit.
8. Complete the meter reading exercises on the following two pages.



TEACHING AID FOR METER READING. To use, stick a pin at black dot. Use a straightedge or a piece of black thread from the dot to the index scale.

LEARNING TO READ A METER

The Index Scale shown at the top of the drawing on page 57 is not a part of the regular meter. It is included on the drawing simply as a means of presenting meter-reading problems.

Practice in meter reading may be obtained by making use of the teaching aid shown on the previous page.

On the Index Scale, each mark between the numbers equals two tenths. In solving the problems which follow, a ruler or a black thread is placed across the page from the dot in the center of the small circle at the bottom of the page, to the index number at the top of the meter. The selector switch is assumed to be in the position specified in the problem. (Write answers to problems on separate sheet of paper.)

I. Selector Switch — 300 volts dc

Index	Meter Reading
3.0	- -
6.2	- -
10.0	- -
5.8	- -

II. Selector Switch — 60 volts dc

Index	Meter Reading
2.0	- -
9.4	- -
7.4	- -
11.4	- -

III. Selector Switch — 12 volts dc

Index	Meter Reading
4.4	- -
9.2	- -
5.8	- -

IV. Selector Switch — 3 volts dc

Index	Meter Reading
2.0	- -
11.0	- -
4.6	- -

V. Selector Switch — × 1 ohms

Index	Meter Reading
10.6	- -
4.8	- -

VI. Selector Switch — × 10 ohms

Index	Meter Reading
4.0	- -
9.2	- -

VII. Selector Switch — × 1000 ohms

Index	Meter Reading
2.0	- -
6.6	- -

VIII. Selector Switch — × 100000 ohms

Index	Meter Reading
8.0	- -
4.0	- -

IX. Selector Switch — 12 dc mA

Index	Meter Reading
9.0	- -
3.2	- -

X. Selector Switch — 1.2 dc mA

Index	Meter Reading
9.0	- -
5.2	- -

XI. Selector Switch — 1.2 dc volts

Index	Meter Reading
3.0	- -
8.0	- -
5.4	- -

Unit 12

GENERATORS

After studying this unit, you will be able to answer these questions:

1. **How is mechanical energy converted to electrical energy?**

2. **What is the theory and operation of the generator?**

A generator can be considered as the opposite of the motor. A MOTOR converts electrical energy to mechanical energy; a GENERATOR converts mechanical energy to electrical energy. The actual construction of both devices is very similar.

For many years, scientists were familiar with the electromagnet. They knew that electricity could produce magnetism. It was not until the experiments of the renowned Michael Faraday in 1831 that the means was discovered to change magnetism into electricity. The story is told that for many months, young Faraday carried around in his pockets a magnet, a coil of wire, and a galvanometer, an instrument which indicated flow of electricity in a conductor.

Late one afternoon, Faraday sat in his laboratory, discouraged. He had reached the conclusion that it was impossible to get electricity from magnetism. His research and experimentation had been unproductive. The coil and the galvanometer lay on the workbench. As Faraday was about to quit for the day, he took the magnet from his pocket and tossed it on the bench beside the coil. Lo and behold! As the magnet passed by the coil of wire, the galvanometer indicated a current flowing momentarily in the coil. It was a day of celebration. One of the most profound discoveries in the science of electricity had been made. We owe much to this great scientist, for the electricity which is used in our homes and industry today is the result of these electrical principles discovered by Faraday. Michael Faraday is remembered as the "father of the dynamo."

Summarizing this story of magnetism and electricity, it was discovered that in order to produce an electric current from magnetism, three conditions must exist.

1. ONE MUST HAVE A MAGNETIC FIELD.
2. ONE MUST HAVE A CONDUCTOR.
3. THERE MUST BE RELATIVE MOTION BETWEEN THE FIELD AND THE CONDUCTOR. EITHER THE FIELD MUST MOVE OR THE CONDUCTOR MUST MOVE.

You can perform a simple experiment to prove this principle. Wind several turns of wire into a coil about two inches in diameter, and connect the ends of the coil to a galvanometer. Now pass the coil back and forth between the poles of a horseshoe magnet. Notice how the indicating needle moves. As you pass the coil down through the magnetic field, the indicator moves in one direction. As you bring the coil up through the magnetic field, the indicator moves in the opposite direction.

DIRECTION OF CURRENT FLOW

It is frequently necessary to determine the direction of the current flow in a conductor as it passes through a magnetic field. Referring to Fig. 12-1, hold your left hand with fingers extended and your thumb at a right angle to your fingers. Point your fingers in the direction of the magnetic field or toward the south pole. If the conductor moves toward the palm of your hand, your thumb will point to the direction of current flow.

One other consideration is the intensity of the current flow. It is easy to see that no current will flow when the conductor is outside of the magnetic field. As the conductor first enters the field a little current starts to flow. The current increases as the conductor moves toward the half way point or to the center, where the magnetic field is the strongest. Then

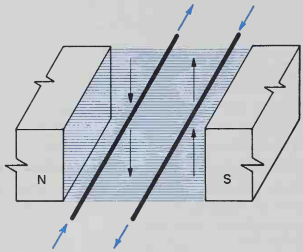


Fig. 12-1. The direction of current flow as the conductor passes through a magnetic field.

as the conductor moves away from the center, the current decreases until it becomes zero when the conductor has passed out of the field on the other side. Fig. 12-2 shows this current flow graphically.

To further develop our graph we can add the curve which will show the current flow as the conductor is moved down through the field. When drawing such a graph, the curve above zero line indicates current in one direction and the curve below the zero line shows current in the opposite direction. Fig. 12-3 is the complete graph of current flow made by one upward movement and one downward movement of the conductor through the field.

THE GENERATOR

In order to create a continuous motion of a conductor through a field, it is convenient to

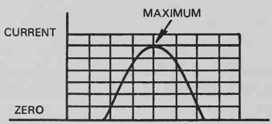


Fig. 12-2. Current starts at zero, rises to maximum amperage and returns to zero as conductor cuts across field.

have a coil rotate in the field. In Fig. 12-4 a single loop of wire is arranged to rotate in the field. The curved arrow shows the direction of rotation. As side A of the coil passes up through the field, a current flows in the direction indicated by the arrows (use your left hand rule to determine direction). Also, at the same time, side B is moving down through the field. Current flows into side B and out of side A. As the coil turns one quarter turn, the sides of the loop coil are parallel to the lines of the field and are not cutting through them. At this point the current is zero, Fig. 12-5.

As the coil continues its rotation, side A cuts down through the field and side B cuts up through the field. A current flows, but in the

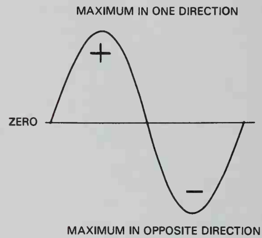


Fig. 12-3. A graph showing the current flow for one upward and one downward movement of the conductor.

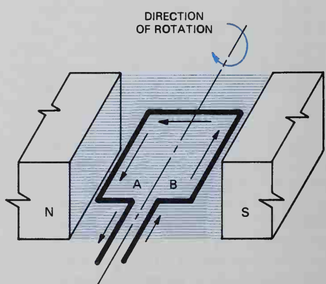


Fig. 12-4. A rotating loop is placed in the magnetic field.

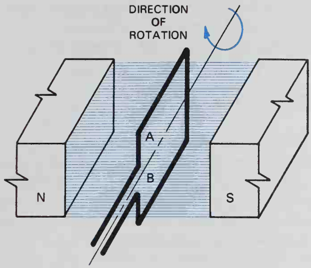


Fig. 12-5. No current is induced when the coil moves parallel to the magnetic field.

opposite direction out of side B and into side A, Fig. 12-6.

Continuous rotation produces a current in the armature coil, which is reversing its direction every half revolution of the coil. A current

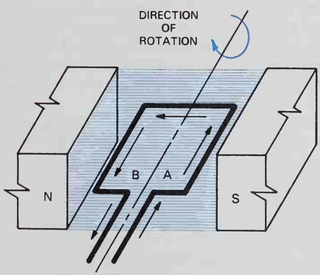


Fig. 12-6. Maximum current is induced when the coil cuts across or moves perpendicular to the field.

which changes its direction periodically is known as an ALTERNATING CURRENT or ac. All generators are alternating current generators. However, some have an output of direct current, dc.

THE COMMUTATOR

You will notice a similarity between the dc motor commutator and the dc generator commutator. They both serve the same purpose; Figs. 12-4 and 12-6 have been redrawn in Figs. 12-7 and 12-8 to include the commutator bars, the brushes, and an external circuit.

To understand the commutator action, trace the current flow which is shown by arrows. In Fig. 12-7, side A of the loop is cutting up

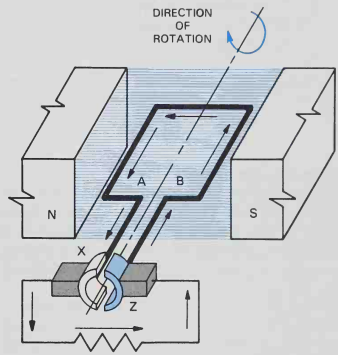


Fig. 12-7. Current flows into side B and out of side A of the coil.

through the field and side B is cutting down through the field. Current flows out of side A, to commutator bar X. The brush collects current and it flows through external circuit to commutator bar Z and into side B of the coil.

As the coil and commutator sections rotate through one-half turn, the situation is like Fig. 12-8. The current is reversed in the loop coil, but the commutator bars have also changed position. Now the current flows out of B to bar Z, through the external circuit to bar X and into side A of the coil. Follow the current arrows. It is important to remember, that although the

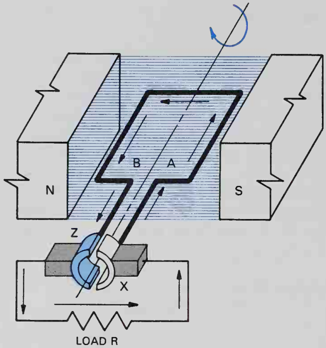


Fig. 12-8. Current flows into side A and out of side B of the coil.

current is alternating in the coil, the current in the external circuit is flowing in only one direction, or is a DIRECT CURRENT. Using our graph again to show the current flow, it appears as pulses of current flowing all above the zero line or rising and falling, but in one direction only, Fig. 12-9.

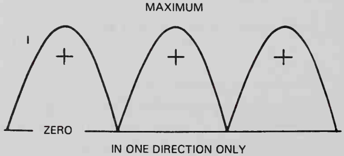


Fig. 12-9. The waveform of the current in the external circuit of the generator.

We have constructed a simple dc generator. Two improvements must be made to make it practical.

1. A stronger current must be generated.
2. A smoother current (less ripple) must be generated, because a pulsing direct current is not satisfactory for many kinds of equipment.

GENERATOR OUTPUT

The simple generator which has been described, uses only a single loop of wire rotating in the field. The currents generated are weak. To improve the output, the rotating coil can be made of many turns of wire. Such is the case in the armature of a practical generator. Likewise, the magnetic field in which the armature rotates can be made a great deal stronger by the use of field windings and electromagnets.

The examination of Fig. 12-9 will disclose that a generator using a single rotating coil for an armature will generate two pulses of direct current per revolution of the armature. By increasing the number of coils in the armature, with a corresponding increase in commutator bars, a greater number of direct current pulses may be obtained from one revolution of the armature.

In Fig. 12-10, the curves show the current flow from a two-coil armature. You will notice that as the current starts to drop in the first coil, the current is rising in the second coil. The resulting current has a lesser degree of ripple and is easier to filter into a pure direct current.

Commercial generators have many windings on the armatures and produce almost a pure direct current.

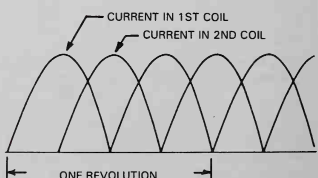


Fig. 12-10. The waveform in the external circuit of the generator with a two-coil armature.

GENERATOR LOSSES

All of the current produced by the generator does not serve a useful purpose. There are losses within the generator itself, which take the form of dissipated heat.

In our study of resistance we learned that all conductors offer some resistance to the flow of current. In a generator many feet of copper wire are used in the armature and field windings. This resistance is a loss and takes the form of heat. It can be measured in watts of power lost:

$P = I^2R$ where:

P = power loss

I^2 = current squared

R = resistance in ohms

The losses resulting from this source are known as COPPER LOSSES.

A second important loss in the generator is known as HYSTERESIS LOSS. Hysteresis sometimes is defined as molecular friction. Due to the rotation of the armature, the groups of molecules in the core of the armature are constantly changing polarity. This internal changing polarity creates a heat within the core which is a loss. Special alloy steels and heat treating processes have been discovered which will reduce the hysteresis loss of the armature core.

A third loss in the armature is known as the EDDY-CURRENT LOSS. This loss can be understood when one realizes that not only is a current being generated in the windings of the armature, but also currents are being generated in the core on which the windings are wound. The currents circulate back and forth in the core. Eddy-current losses are overcome by LAMINATING the core of the armature. This means that the core is made up of layers of metal, rather than one solid piece of steel. Plywood is an excellent example of lamination in the wood industry. Contrast a piece of plywood with solid wood.

FIELD EXCITATION

In order for the generator to operate, it must have a magnetic field. In the case of the permanent field magnets, of course, the field is there. But this field was weak and we have introduced electromagnets to replace them. An electromagnet requires electricity for its magnetic field, Fig. 12-11.

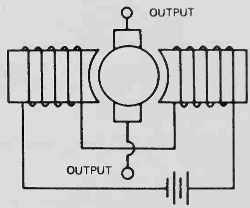


Fig. 12-11. Diagram of a generator with external field excitation.

The field windings of a generator may be INDEPENDENTLY EXCITED by a direct current source such as a battery. Using the same diagrams as we used for a motor, this circuit would appear as in Fig. 12-11.

A second method of exciting the fields is widely used in industry and is called a SHUNT GENERATOR. The generator gets its start from a small amount of residual magnetism left in the field poles. As current builds up, a part of its output is used to excite its field windings. Fig. 12-12 is an example of this circuit.

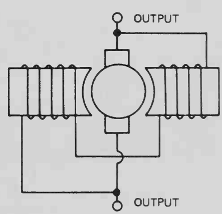


Fig. 12-12. Diagram of a shunt wound generator.

A generator may also be connected with the field in series with the armature. It would be a SERIES GENERATOR and is not a popular method.

A combination of series and shunt connections does have many applications in commercial generators. It is known as a COMPOUND GENERATOR.

QUIZ — UNIT 12

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Who is known as the "father of the dynamo?"
2. What is meant by copper losses?
3. What is meant by eddy-current loss?
4. What is hysteresis loss?
5. How are eddy-current losses minimized?
6. Classify generators into four types, depending on method of field excitation.
7. What is the purpose of the commutator in the generator?
8. In order to induce a current to flow in a conductor three conditions must exist. You must have a magnetic field, a conductor, and ________.
9. What is the advantage of having several coils of wire on the armature?
10. Draw a circuit diagram of a shunt generator.
11. How does a shunt generator get its initial field excitation?
12. If a variable resistor were connected in series with the field windings of a generator, it would be possible to manually control the output of the generator. Explain why this is true or untrue.

There are career opportunities at many levels of skill in the electricity industries. Pictured above are members of a class in meter reading. (Philadelphia Electric Co.)

Unit 13
ALTERNATING CURRENT

After studying this unit, you will be able to answer these questions:

1. **How does an ac generator differ from the dc generator?**
2. **What is a sine wave?**
3. **What is meant by phase relationship?**
4. **How can dc current be compared with ac current?**

In our lesson on direct current generators, we learned that actually an alternating current was generated in the rotating armature. However, due to the commutator, the alternating current (ac) appeared as direct current (dc) in the output of the generator.

In our country the most common form of electrical current used is alternating current. It is used in industry to run motors that turn machines. It is used in the home for lighting, heating, cooking, and for many other kinds of labor-saving appliances.

Electric power plants are located in our cities, in rural areas, and on our rivers. A power generating plant converts energy into electrical energy. In the case of the steam plant, coal is burned to make steam, which drives turbines and generators. In the hydroelectric plant, the energy of falling water is changed to electric energy as the water turns turbines and generators. Nuclear power is used as a means of generating electricity, Fig. 13-1.

Fig. 13-1. Nuclear powered electricity generating plant. (U.S. Dept. of Energy)

The ac generator is similar to our simple dc generator with one exception. The commutator has been replaced with SLIP RINGS, Fig. 13-2.

A slip ring is connected to each end of the coil. The brushes are in constant sliding contact with the rings providing a way to pick up the electrical energy generated in the rotating armature.

The changing polarity and changing direction of current in the rotating armature has already been explained in the unit on principles of the

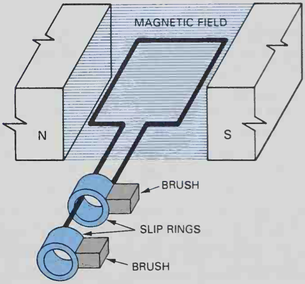


Fig. 13-2. The alternating current generator has slip rings instead of a commutator.

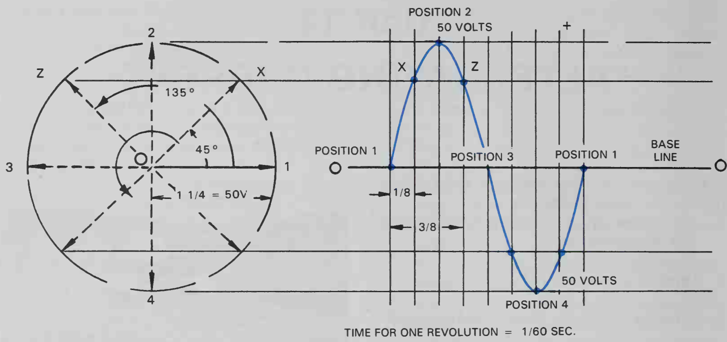


Fig. 13-3. The development of a sine wave.

generator. The important thing to remember, in the case of the ac generator, is that the current in an external circuit connected to the brushes of the generator is an ALTERNATING CURRENT PERIODICALLY RISING AND FALLING AND CHANGING DIRECTION, the same as the current in the armature.

VECTORS AND SINE WAVES

The engineer and technician has a convenient way of representing a force by means of a vector. A VECTOR is simply an arrow. The length of the arrow represents the magnitude of the force and the direction of the arrow is pointing is the direction in which the force is acting. It is a lot of fun to work with vectors. They are sometimes called graphical mathematics. The vector may be used to represent the magnitude of a generated voltage and the direction in which electromotive force is acting or causing a current to flow. For example, let's assume the generator can produce a voltage of 50 volts. (Scale 1/4 in. = 10 volts), Fig. 13-3. The vector will rotate around point O in a counterclockwise direction, and can be compared to the rotating armature of the generator.

Fig. 13-4 shows the rotating armature in four positions. Now follow the explanation using both Figs. 13-3 and 13-4.

Position 1. Conductor not cutting field. No voltage.

Position 2. Conductor in center of field. Maximum voltage. Positive.

Position 3. Conductor not cutting field. No voltage.

Position 4. Conductor cutting center of field. Maximum voltage. Negative.

The positive voltage is a force in one direction and the negative is a force in the opposite direction. Current flow likewise would correspond to the direction of the force or voltage.

Assuming that the armature is revolving at a speed of 60 revolutions per second, the elapsed time for one revolution would be one-sixtieth of a second. Along the base line in Fig. 13-3, let any convenient distance equal one-sixtieth of a second. The voltage starting at zero, rises to maximum force in one direction (position 2) then at the end of 180° rotation returns to zero, (position 3). In the next 90° of rotation the voltage rises to maximum but in the opposite direction (position 4). In the last 90° the voltage returns to zero (position 1).

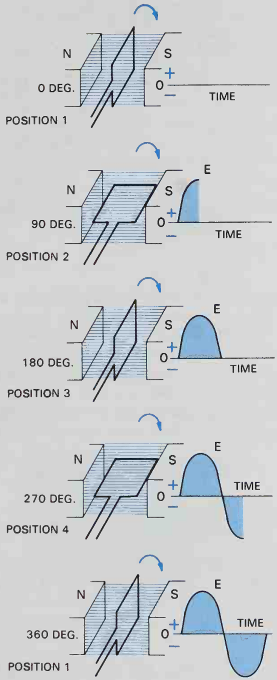


Fig. 13-4. Compare the pictures of the vector and the rotating armature coil.

The curve in Fig. 13-3 is a graph of the instantaneous voltages and represents the rise and fall of the voltage during one revolution. Points X and Z have been plotted. The curve is the result of a line drawn through several plotted points. Point X is taken at 45° revolution and at one-eighth of the time base distance. Point 2 at 90° revolution and 1/4 of the time base. Point Z at 135° revolution and three-eighths of the time base. Many points may be plotted to get a very accurate curve. The curve is known as the SINE WAVE and represents an alternating current or voltage.

The term "sine wave" will give you an introduction to trigonometry. It shows that the instantaneous voltage developed at any point on the sine wave depends upon the degrees of rotation of the vector.

FREQUENCY

The chain of events described in the previous examples, represents ONE CYCLE of operation. You will notice that from position 4, the vector returns to position 1 and the whole sequence of events repeats over and over for each revolution of the vector. The sine wave is a graphic picture of the instantaneous voltages during one cycle of generation. If the time duration of one cycle is one-sixtieth of a second, then the FREQUENCY of the generated voltage is 60 CYCLES PER SECOND. This is the standard frequency of the alternating current we use in our homes.

The term "cycles per second" is gradually becoming obsolete. The term HERTZ replaces it. One HERTZ equals one cycle per second. A 60 cycles per second wave becomes 60 Hz. (Note abbreviation.)

PERIOD

It is also important to be familiar with the time duration of a wave which is called its PERIOD. In the previous example the PERIOD is 1/60 of a second. It is also a 60 Hertz wave. Therefore an equation can be written which tells us that,

$$\text{PERIOD (in seconds)} = \frac{1}{\text{frequency in hertz}}$$

Using another example of a 1000 Hz wave. Its PERIOD would be,

$$\text{PERIOD} = \frac{1}{1000 \text{ Hz}}$$

or .001 seconds.

The generator which we have discussed would be known as a SINGLE-PHASE GENERATOR. It would be possible to place a second coil in the generator which would produce another voltage. Usually this coil is so spaced that the second voltage will be 90° out-of-step or out-of-phase with the first

voltage. The waveform of output of this generator is shown in Fig. 13-5.

Voltage A is 90° out-of-phase with voltage B, or there is a 90° PHASE DISPLACEMENT. Such a generator is a two-phase generator. The output circuits may be connected to use either voltage A or voltage B, or both voltages in series.

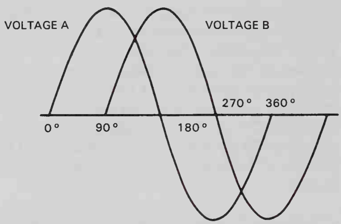


Fig. 13-5. The waveform of a two-phase alternating current.

A third very common type of alternator or generator is three-phase. In this machine the coils are spaced 120° apart and three separate voltages are generated. Each voltage has a phase displacement of 120°. The output wave is shown in Fig. 13-6. Voltage B is 120° out-of-phase with voltage A, and voltage C is 120° out-of-phase with voltage B.

AVERAGE VALUES

A close look at the sine wave for ONE HALF a cycle or one alternation will disclose that the

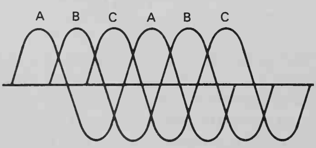


Fig. 13-6. The waveform of a three-phase alternating current.

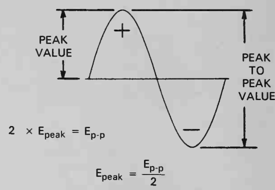


Fig. 13-7. The waveform showing the instantaneous peak voltage.

voltage is continuously varying. It starts at zero and rises to maximum or PEAK voltage and then returns to zero, Fig. 13-7. The value of this voltage could not be considered as equal to its peak voltage, because the peak is reached at only one point during the half cycle. One can find an average voltage or the average current represented by a sine wave by the formula:

$$E_{average} = .637 \times E_{peak}$$

or

$$E_{peak} = 1.57 \times E_{average}$$

PROBLEM: What is the average value of an alternating voltage which has a peak voltage of 50 volts?

$$E_{av} = .637 \times 50 = 31.85 \text{ volts}$$

Carefully note that the AVERAGE VALUE is computed as the average value of one half cycle. The average value of a complete cycle would be ZERO.

EFFECTIVE VALUES

A more meaningful value of an alternating current is its EFFECTIVE VALUE. To determine the effective value, the current is compared to a direct current. In other words, if a direct current will produce a certain power, what equivalent alternating current will produce the same power?

If a load, such as a resistor, were connected across an ac circuit, the instantaneous currents between zero and peak could be taken and the

effective power could be found. As power equals,

$$P = I^2R$$

All these instantaneous currents could be squared and added together. Dividing the sum by the number of currents used would give the average of the squared currents. The square root of this value is known as the RMS or ROOT-MEAN-SQUARE. It is found to be .707 times the peak value.

$$RMS = .707 \times E_{peak}$$

PROBLEM: To find the effective value of a 20 ampere peak current.

$$20 \times .707 = 14.14 \text{ amps}$$

A 20 ampere peak alternating current will have an effective value equal to 14.14 amps of direct current.

A summary of these formulas for average and effective values is as follows:

$$\begin{aligned} E_{eff} &= .707 \times E_{peak} \\ E_{peak} &= 1.41 \times E_{eff} \\ E_{avg} &= .637 \times E_{peak} \\ E_{peak} &= 1.57 \times E_{avg} \\ E_{eff} &= 1.11 \times E_{avg} \\ E_{avg} &= .9 \times E_{eff} \end{aligned}$$

Most meters that you will use indicate effective alternating current and voltage.

Another value of an ac wave you should recognize is its PEAK TO PEAK value. Study Fig. 13-7 and note these values. The peak to peak value of a wave always appears on an oscilloscope which is one of the basic instruments used in observing and measuring ac waves.

QUIZ — UNIT 13

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. On graph paper, construct a sine wave. Show the rotating vector and plot points at 30 degree intervals of rotation.
2. A dc generator uses a commutator, but the ac generator has ________.
3. A vector represents the ________ and ________ of a force.
4. What is the effective value of a 150 peak voltage?
5. What is the peak voltage of the electricity in your home which is rated at 110 volts?
6. Meters usually read in ________ voltage and current.
7. On graph paper draw a single-phase wave, a two-phase wave, and a three-phase wave.
8. What is the RMS of an average voltage of 90 volts?
9. Frequency of an alternating wave is measured in ________.
10. A certain electric current has a frequency of 400 Hz. What is the time interval or period of one cycle?

Unit 14

TRANSFORMERS

After studying this unit, you will be able to answer these questions:

1. **What is the theory of the operation of a transformer?**
2. **Can you list common applications of the transformer?**
3. **What is the theory and operation of induction coils?**

A TRANSFORMER is a device used to transfer electrical power from one circuit to another.

To understand how this can be done, first review the lessons on the generator. You will remember the experiments of Michael Faraday when he discovered the principles by which an electric current could be produced from a magnetic field. In our simple generator the magnetic field was created by the field windings and magnets. The rotating armature supplied the conductors and the relative motion between the field and conductors. Another way to produce a similar effect would be to hold the conductor stationary and move the magnetic field. Would this not produce the same result?

In the study of the transformer we will first look at an ordinary electromagnet to which is connected a source of alternating current. As the alternating current rises to maximum flow in one direction the magnetic field expands outward to maximum strength. As current decreases, the magnetic field decreases or collapses until it reaches the zero point. The alternating current then rises to maximum in the opposite direction, creating a magnetic field with opposite polarity. An alternating current, therefore, produces a moving magnetic field, ever-changing in its strength and polarity at the same frequency as the applied alternating current.

If a conductor or coil is placed close to this varying magnetic field, a current will be INDUCED to flow in this coil. The magnetic lines of force of the electromagnet cutting across the coil will induce current flow in it. Fig. 14-1 is a schematic diagram of such a device.

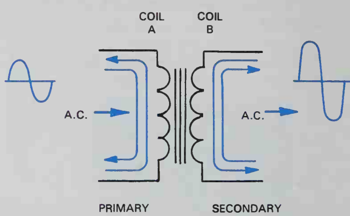


Fig. 14-1. The schematic diagram of a transformer.

Coil A produces the ever-changing magnetic field. It is called the PRIMARY WINDING. The induced current flows in coil B. It is known as the SECONDARY WINDING. The number of lines of magnetic flux that link the primary coil and secondary coil together, depends on the distance between them. This is called COUPLING. In the transformer, the windings are so arranged that all the lines of magnetic flux of coil A will cut across coil B. This would be UNITY COUPLING. In practice, the secondary windings are wound over the primary windings on the same iron core.

LENZ'S LAW

It is important to remember that when a current flows and a magnetic field is produced in the primary; THE INDUCED CURRENT FLOW IN THE SECONDARY WILL BE IN THE OPPOSITE

DIRECTION AND CREATING A MAGNETIC FIELD OF OPPOSITE POLARITY. In other words, the induced magnetic field opposes the primary magnetic field. This is known as the Lenz's Law.

TRANSFORMER LOSSES

The transformer is a very efficient device. However, some losses during the transfer of power do occur.

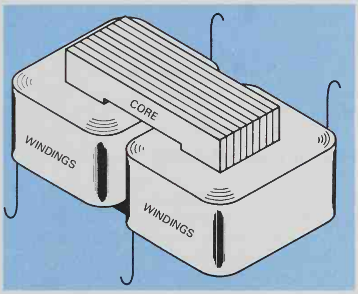


Fig. 14.2 A core-type transformer.

1. COPPER LOSSES. Created by the resistance of the copper wire in the windings.
2. EDDY-CURRENT LOSSES. Overcome by making the transformer core out of many thin sheets of iron, insulated from each other, called LAMINATIONS.
3. HYSTERESIS LOSS from molecular friction in the iron core. This is overcome by using special silicon steel and heat treating processes for core materials.

TRANSFORMER CONSTRUCTION

Two common methods of transformer construction are used. In the first place, the primary and secondary windings are wound on each side of a laminated core in the form of a rectangle, Fig. 14-2.

This is a CORE-TYPE TRANSFORMER. You might assume that the primary was wound on one side and the secondary on the other. Such is not the case however. Part of each winding is wound on each side to overcome coupling losses.

A second method known as the SHELL-TYPE TRANSFORMER, has the primary and secondary windings together on the center section of a laminated core, Fig. 14-3.

A distinguishing characteristic of these types of transformers is that in the core-type, the windings are around the core. In the shell-type the core is around the windings. Each type has special applications in the distribution and conversion of electrical power.

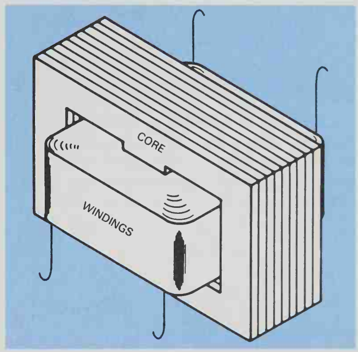


Fig. 14-3. A shell-type transformer.

TURNS RATIO

If there is an equal number of turns in both the primary and secondary windings, the magnetic flux cuts across both windings and induces a voltage in the secondary which is the same as thee voltage applied to the primary. Such a transformer has applications as an ISOLATION transformer. It provides a physical separation between a circuit and the applied ac

power. Service technicians sometimes use the isolation transformer as a protective device against electric shocks and for the protection of expensive test equipment.

However, if there were twice as many secondary windings as primary windings, then each line of magnetic flux of the primary would cut across two secondary windings and the induced voltage would be twice the value of the applied voltage. Any combination of windings might be used and the secondary voltage varies in respect to the primary voltage as the relationship between the number of turns of wire in each. The formula appears as,

$$\frac{E_{in}}{E_{out}} = \frac{N_{primary}}{N_{secondary}}$$

where,

E_{in} = Applied voltage
E_{out} = Voltage of secondary
N_p = Number of turns in primary
N_s = Number of turns in secondary

A problem: A transformer has 200 turns in the primary and 1000 turns in the secondary. If the applied voltage is 100 volts, what is the secondary voltage? Substituting the known quantities in the formula, we have:

$$\frac{100}{E_{out}} = \frac{200}{1000}$$

or

$$E_{out} = \frac{100000}{200} = 500 \text{ volts}$$

The relationship between the number of turns in the primary and secondary is known as the TURNS RATIO.

A transformer which raises the voltage is a STEP-UP transformer. Conversely, a STEP-DOWN transformer lowers the voltage.

Transformers may have several secondary windings to provide low and high voltages for the operation of various circuits. A common type is the power transformer in Fig. 14-4. Transformers are also used as coupling devices for radio frequency signals.

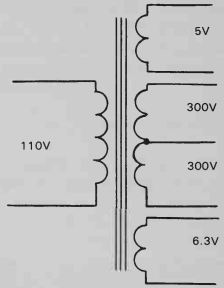


Fig. 14-4. The schematic diagram of a power transformer.

POWER TRANSMISSION

The following question is usually asked the beginning student of electricity: "Why is alternating current almost universally used in home and industry in the United States?" The answer to the question is that the transformer can be used more conveniently with an alternating current.

To understand this, we will review some of our background. A wire has a certain resistance to the flow of electricity and a loss of power is the result of this resistance. WATT'S LAW says that:

$$P = I^2R$$

Because power loss increases as the square of the current, the loss becomes quite a factor when the current is increased. Compare these examples. With 10 amps of current flowing through one ohm of resistance, the loss equals:

$$P = 10^2 \times 1 \text{ or } 100 \text{ watts}$$

If the current were increased to twice the value of 20 amps, then the loss would be:

$$P = 20^2 \times 1 \text{ or } 400 \text{ watts}$$

or four times greater.

It is apparent that the current should be kept as low as possible to avoid power loss.

But power is the product of current times

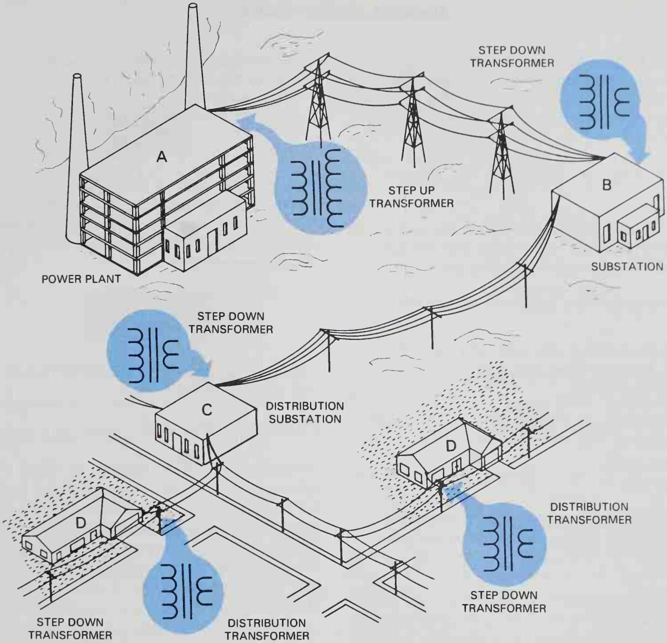


Fig. 14-5. The transmission of power from the generator to your home.

voltage: various combinations of I and E could produce the same power such as:

$$100\text{ V} \times 10\text{ amps} = 1000\text{ watts}$$
$$1000\text{ V} \times 1\text{ amp} = 1000\text{ watts}$$
$$10000\text{ V} \times .1\text{ amp} = 1000\text{ watts}$$
$$100000\text{ V} \times .01\text{ amp} = 1000\text{ watts}$$

If a large quantity of electrical energy is to be conducted over a long distance such as from a power plant in the mountains to a city a hundred miles away, the transformer can be used to overcome the power loss. In the power plant the voltage is stepped-up to a very high value by transformers. The electricity is conducted to the city by high tension power lines. At the city the voltage is stepped-down by transformers to safe voltages for use in your home. On a pole near your house, you will probably find a rather large transformer used to bring the voltage down to 110-120 volts.

A sketch in Fig. 14-5, shows the sequence of events. If 12000 watts (12 kW) of power were transmitted from power house A to your home at point D, trace the current flow in each leg of the transmission circuit.

At the power plant generator:

$$I = \frac{P}{E} = \frac{12000\text{ W}}{12000\text{ V}} = 1\text{ amp}$$

The transformer at the power generator steps-up the voltage to 60000 volts. The current required for 12 kilowatts in the transmission line from the power plant (A) to the substation (B) will be only .2 amps.

$$I = \frac{P}{E} = \frac{12000\ W}{60000\ V} = .2 \text{ amps}$$

In the city at a substation (B) the voltage is stepped-down to 1200 volts and the current for 12 kW of power will be 10 amps.

$$I = \frac{P}{E} = \frac{12000\ W}{1200\ V} = 10 \text{ amps}$$

Before entering your home (D) the voltage is again stepped-down and the current you are actually using is,

$$I = \frac{P}{E} = \frac{12000\ W}{120\ V} = 100 \text{ amps}$$

Summarizing

At point	E	×	I = P
A	12000	×	1 = 12000 W
A—B	60000	×	.2 = 12000 W
B—C	1200	×	10 = 12000 W
D	120	×	100 = 12000 W

When you remember that the current carrying capacity of a wire depends upon its size, you will see some distinct advantages to stepping the voltage up before transmission across the country. Smaller wires can be used. Small wires are more economical and easier to install and maintain.

Although smaller wires do add more resistance to the circuit, this power loss is more than offset by the savings made by using the small conductors.

Some observations can be made from the previous example of power transmission. A transformer cannot increase power. It is not a generating device. Power output would always be equal to power input, neglecting any losses caused by the transformer.

Power in Primary = Power in Secondary

But: Power = I × E
Therefore,

$$I_{primary} \times E_{primary} = I_{secondary} \times E_{secondary}$$

In a transformer the secondary voltage varies directly as the TURNS RATIO:

$$\frac{E_p}{E_s} = \frac{N_p}{N_s}$$

Therefore: in order to keep $P_{pri} = P_{sec}$ an increase in voltage must be accompanied with a DECREASE in current. Also, a decrease in voltage must have an INCREASE in current. In respect to current,

$$\frac{I_{pri}}{I_{sec}} = \frac{N_{sec}}{N_{pri}}$$

CURRENT IS INVERSELY PROPORTIONAL TO THE TURNS RATIO.

THE INDUCTION COIL

Frequently it is necessary to raise a dc voltage for use in electrical equipment. Among the many examples one could use to illustrate this transformer action is the ignition system of the automobile. The battery has a dc voltage of 12 volts. In order to cause dc spark to jump a gap in the spark plugs, a voltage of some 20000 volts is needed.

To do this, the current in the primary windings of the transformer is made to vary by the opening and closing of a mechanical switch. This pulsating direct current will create a varying magnetic field which will induce a current to flow in the secondary windings. The switch in the primary circuit is referred to as the BREAKER POINTS and is actuated by a shaft connected to the engine. The schematic of this circuit is shown in Fig. 14-6. The transformer in this automotive circuit is known as the COIL. The breaker points may be found in the distributor.

Another variation of the induction coil is one that uses magnetism of the primary to open the points and break the circuit, Fig. 14-7.

In this circuit, the current flowing in the primary makes an electromagnet which pulls the points open. When this occurs, the primary current falls to zero, the magnetism disappears and the spring pulls the points together again.

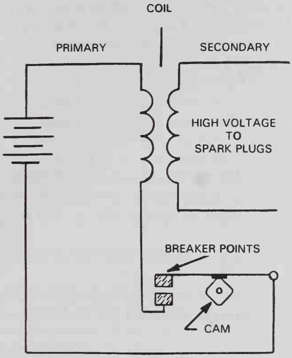


Fig. 14-6. A simplified diagram of an automotive ignition system.

This causes current to flow again. The action goes on as long as there is an applied voltage. A higher voltage is induced in the secondary.

Now you have enough understanding of transformers to construct the INDUCTION COIL, Project 8. This induction coil will demonstrate transformer action and induced voltage.

This same circuit without the secondary winding is used as a door buzzer and when a bell striker is attached to the moving point, a doorbell can be made, Fig. 14-8.

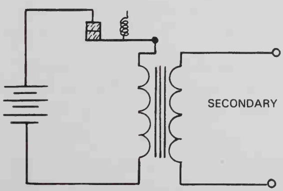


Fig. 14-7. A diagram of an induction coil.

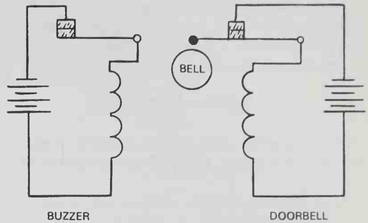


Fig. 14-8. Simplified diagram of a doorbell and buzzer.

Circuits in the MAGNETIC RELAY, Project 6 will demonstrate how to connect the RELAY as a BUZZER. It is easy to build and it will add to your knowledge of electricity and magnetism.

AUTOTRANSFORMER

It is possible to construct a transformer with only one winding which serves as both the primary and the secondary. Refer to Fig. 14-9. Such a device is called an AUTOTRANSFORMER. The primary is connected across the line. A tap on the primary is provided for one end of the secondary. The ratio of the input and output voltage is in proportion to the turns ratio, however, the current flow in the secondary is low because the induced current flows in the opposite direction from the primary current. Hence the net current is the difference between the two currents.

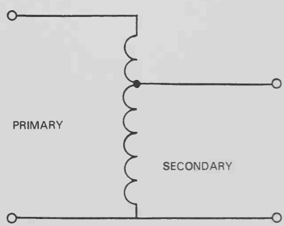


Fig. 14-9. The schematic diagram of a step-down autotransformer.

An autotransformer is used in many television sets to produce the high voltage to operate the picture tube. In this application it would be a step-up transformer.

QUIZ — UNIT 14

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. A device used to transfer energy from one circuit to another is called a ________.
2. Draw the schematic symbol for a power transformer.
3. The transformer has two sets of windings known as the ________ and ________ coils.
4. The input and output voltages of a transformer vary as the ________.
5. A certain transformer has an input voltage of 100 volts. Assuming the primary has 200 turns, compute the turns in the secondary for:
   600 volts ________ turns
   10 volts ________ turns
   20 volts ________ turns
6. Draw the circuit of an induction coil.
7. Draw the circuit for a door buzzer.
8. Explain why alternating current is used in the transmission of electric power.
9. Name three losses that occur in a transformer.
10. Eddy-current losses are prevented by ________ construction.
11. Draw a circuit of a relay operated with a 6 volt battery controlling a 110 volt motor circuit.
12. What is the purpose of a circuit breaker?

Unit 15

INDUCTANCE

After studying this unit, you will be able to answer these questions:

1. What is inductance in a circuit?

2. What is reactance?

By definition, INDUCTANCE is that property of a circuit which opposes any change in current in a circuit. Let's explore the meaning of this definition and show how it can be proved. A review of Magnetism, Unit 9, may be necessary. Associated with a conductor carrying a current will be a magnetic field. If the conductor is wound into a coil around a core, the magnetic fields around each turn of the coil join and reinforce each other so that the coil becomes an electromagnet with a definite NORTH-SOUTH polarity. Existing in space around the coil will be many invisible magnetic lines of force. It could be a large and strong magnetic field or it could be a weak magnetic field depending upon the value of the current through the coil.

SELF INDUCTANCE

In Generators, Unit 12, the discoveries made by Faraday were used to explain generator action. You will recall that three conditions must exist:

1. One must have a conductor.
2. One must have a magnetic field.
3. There must be relative motion between the field and the conductor. Either the conductor must move or the field must move.

In Fig. 15-1, a simple coil of wire has been connected to a dc power source. The switch is open. There is no current flow. There is no magnetic field.

In Fig. 15-2, the switch has been closed and a current flows in the circuit producing a magnetic field around the coil. The greater the current, the stronger the magnetic field. We can conclude then:

1. No current — no magnetic field.
2. Increasing current — increasing magnetic field.
3. Maximum current — maximum magnetic field.

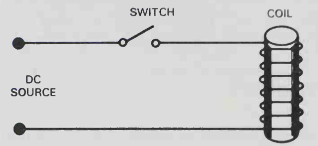


Fig. 15-1. A coil is connected to a dc power source. Switch is open.

Have we not created a MOVING MAGNETIC FIELD? It is expanding outwardly as the current increases; it contracts or moves inwardly as the current decreases. This moving field cuts across the wires which form the coil. This produces a voltage called COUNTER ELECTROMOTIVE FORCE (CEMF) which opposes the source voltage and, therefore, opposes any increase or decrease of current through the

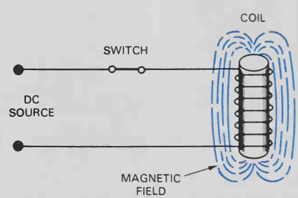


Fig. 15-2. When the switch is closed, a current flows in the circuit and produces a magnetic field.

coil. It is called an INDUCED voltage resulting from the moving magnetic field across the wires of the coil. This phenomenon is described as SELF INDUCTANCE.

It is interesting to note that if a steady direct current of any value, even a thousand amperes, were flowing through the coil it would have no cemf. However, if the current changed even as little as one microampere, a cemf would develop which would oppose that change.

THE HENRY

A coil is called an INDUCTOR. If the rate of change of one ampere per second produces a cemf of one volt, the coil is described as having an inductance of one HENRY. This unit of measurement honors the memory of Joseph Henry, who discovered the self inductive action of a coil in 1830. Many coils, with and without cores, are used in electricity and electronics. They will have values in henrys, millihenrys, and microhenrys depending upon their application. Examples of these coils and the inductor symbol are illustrated in Fig. 15-3.

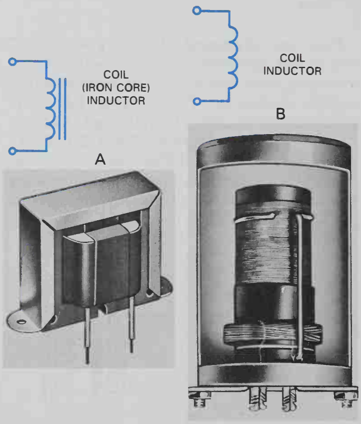


Fig. 15-3. Symbols for coils and examples of coils used in electronic circuits. A—Choke coil used in a power supply. B—An antenna coil.

COIL ACTION IN DC CIRCUIT

Consider the resistance only circuit in Fig. 15-4. When the switch is closed, the current rises to maximum value almost instantaneously and remains at a fixed value as determined by Ohm's Law.

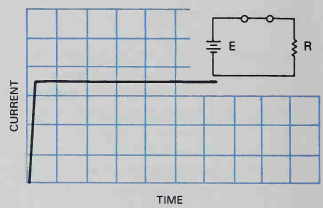


Fig. 15-4. In a resistive circuit, the current rises instantaneously to some fixed value depending on the voltage applied and the value of resistance.

In Fig. 15-5, an inductor is used instead of the resistor. In this case the current does not rise instantaneously, because the rising current induces a counter emf which opposes the rising current. The time delay of the current depends on the inductance of the coil and any resistance which may be in the circuit. The wires of the coil will have some resistance. This delay is called the TIME CONSTANT of the circuit. Mathematically:

$$\text{Time in seconds} = \frac{\text{L in Henrys}}{\text{R in Ohms}}$$

This is the time required for the current to rise to approximately 63 percent of its final value. At the end of FIVE time constant periods, the current is considered to be at its maximum or steady state value. It is important to remember that inductance appears ONLY when there is a change in current. When the current has risen to its STEADY STATE value, there is no inductance and the current flowing in the circuit is limited only by the dc resistance of the circuit.

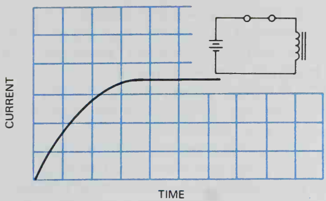


Fig. 15-5. In an inductive circuit, the current rise is delayed because of CEMF induced in the coil by a change in current.

REACTANCE

When an inductor or coil is used in an ac circuit, a new situation develops. Assuming a sine wave ac voltage is applied to the circuit, the current would tend to rise and fall and reverse direction in step with the applied voltage and at the same frequency as the applied voltage. Since a constantly changing current would produce a continuous cemf, the current would never rise to its maximuum value as it did in a dc circuit. The value of the ac current would be determined by the INDUCTANCE OF THE COIL and the FREQUENCY of the applied voltage. This opposition to the flow of ac current is called REACTANCE and it is measured in Ohms just like dc resistance. Its symbol is X and since it is caused by a coil, it is labeled X_L for inductive reactance. The formula appears as:

$X_L = 2\pi fL$

where,

X_L = inductive reactance in ohms.
f = frequency of applied voltage.
L = inductance in henrys of the coil.
π = 3.14

IMPEDANCE

Considering the previous discussion, the inductance and the cemf will prevent the current from rising and falling in step with the applied voltage. There will be a delay and the current will kind of "drag its feet" all the time. In a theoretically pure inductive circuit the current will, in fact, lag behind the applied voltage by 90 deg.

In a purely resistive circuit, the voltage and current rise and fall together in step or IN PHASE. Any circuit which contains both inductance and resistance will cause the current to lag by some angle less than 90 deg. To make this statement in another way: There are two oppositions to the flow of current, the inductive reactance X_L and the dc resistace in ohms. Since the opposition by X_L is 90 deg. out-of-phase with R in ohms, they cannot be added directly together. The resultant of the two oppositions must be found. In Fig. 15-6 an example of this vector addition is illustrated. The resultant of X_L and R is called the IMPEDANCE of the circuit. Its symbol is Z and it is also in ohms.

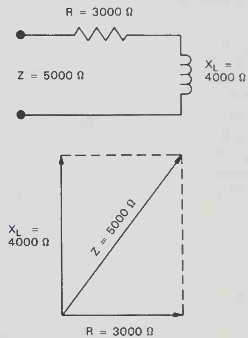


Fig. 15-6. The impedance of a series RL circuit is found by adding X_L and R vectorially since X_L is 90 deg. out of phase with R.

An application of the Pythagorean Theorem in geometry tells us that:

$$Z^2 = R^2 + X_L^2 \text{ or } Z = \sqrt{R^2 + X_L^2}$$

QUIZ — UNIT 15

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Draw the symbol for an inductor.

2. What is the letter symbol for inductance? ________.
3. What is the symbol for inductive reactance?
4. What is the unit of measurement for inductance? ________.
5. What is the formula for inductive reactance?
6. Define inductance.
7. In order to induce an electric current there must be a magnetic field and a conductor. What other condition must also be present?
8. Draw a schematic diagram for an inductance (L) in series with a resistor (R), connected to a battery through a switch (S).
9. Can an inductor be used to filter out variations in current? Explain.
10. Can direct current resistance and reactance be added together like series resistors? Explain.
11. After the current has built up in an inductive circuit and there is no further change, the inductance appears only as resistance in a direct current circuit. Explain.
12. Draw a graph showing the difference between the rise in current in an inductive circuit and a pure resistive circuit.

Unit 16

CAPACITANCE

After studying this unit, you will be able to answer these questions:

1. What is a capacitor?

2. What is the nature of capacitance in a circuit?

3. What is the effect of capacitance in a circuit?

4. What is capacitive reactance?

All circuits in electricity and electronics will have some combinations of resistance (R), inductance (L), and capacitance (C). In previous units we have become acquainted with R and L. Now take a look at capacitance.

CAPACITOR

The illustration in Fig. 16-1 shows two metal plates. These plates are not touching each other. There is AIR insulation between each of the plates. One of the metal plates is connected to the negative side of a battery and the other metal plate is connected to the positive side of the battery. The switch permits the circuit to be turned "on" or "off." A schematic diagram using conventional symbols is also shown in Fig. 16-1.

When the switch is closed, electrons from the negative terminal move toward plate A. Because plate A is very close to plate B, the electrons on A repel the electrons on plate B and these electrons are attracted to the positive battery terminal. Consequently plate A becomes negative (excess of electrons) and plate B becomes positive (fewer electrons). The capacitor is now CHARGED to an equal but opposite voltage of the battery. The capacitor accepts a charge and becomes a voltage source in its own right. The charging action of a capacitor may be studied in Fig. 16-2. It is important to realize that current flows only during the charging action. When the capacitor is fully charged the circuit current drops to zero. No current actually flowed through the capacitor.

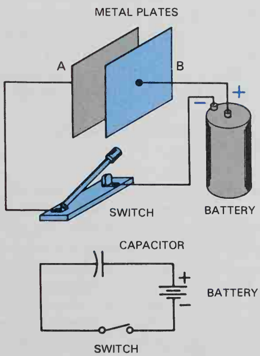


Fig. 16-1. The simple capacitor connected to a battery and the schematic diagram.

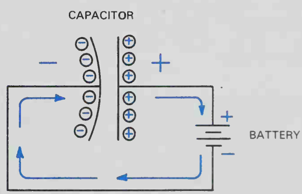


Fig. 16-2. Charging current flows for a fraction of time until capacitor becomes charged.

CHIP SAYS:

"There is frequently a clown in the electronics class who will charge up a capacitor and toss it to you. You'll be surprised when you catch it. DON'T BE A CLOWN. Be a safe and wise technician."

THE CAPACITIVE CIRCUIT

CAPACITANCE is defined as that property of a circuit that opposes a change in voltage. The CAPACITOR is so named because it has the ability to store an electric charge. In Fig. 16-3, it is interesting to observe the current and voltage during capacitor charging. When the switch is initially closed, and C is completely discharged, maximum current starts to flow. As C charges, the charging current becomes less and less until it is zero and C is fully charged. When current is maximum, the charge on C is minimum. When charge of C is maximum, the current is zero. In a capacitive circuit the voltage and current are 90 deg. out-of-phase and the current leads the capacitor voltage by an angle of 90 deg. or less.

THE FARAD

Capacitance is measured in FARADS in honor of Michael Faraday. A capacitor which will store a charge of one coulomb of electrons when one volt is applied is said to have one farad of capacitance. This is a rather large unit. In the practical applications of capacitors, they will have values in MICROFARADS and PICOFARADS.

1 microfarad = 1 μF = one millionth of a FARAD

1 picofarad = 1 pF = one millionth of one millionth of a FARAD

See the prefix chart in Fig. 16-4.

WORKING VOLTAGE

The insulation used between the plates of a capacitor and also the distance between the plates will determine what maximum voltage can be applied to the capacitor without arcing between the plates and destruction of the capacitor. This voltage value will be clearly stated on the capacitor and should not be exceeded. Do not use a capacitor with a working voltage of 10 volts in a 100 volt circuit.

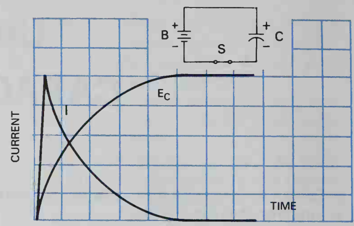


Fig. 16-3. As the capacitor becomes charged the current drops to zero.

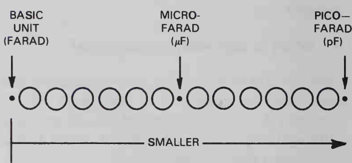


Fig. 16-4. Prefixes for capacitance units.

FACTORS WHICH DETERMINE CAPACITANCE

Some of these factors have already been mentioned. Naturally larger plates (greater area) will store more electrons. The distance between the plates will be a factor since closer plates cause a greater density of electrostatic fields. Also, the kind of insulation or DIELECTRIC between the plates will vary in its ability to concentrate the fields. This factor is the DIELECTRIC CONSTANT of a material and refers to its ability in respect to air or vacuum which is 1. For examples: Mica is about 5, or five times better than air. Waxed paper has a

dielectric constant of about 3. Summarizing these effects, capacitance varies:

1. Directly with plate area.
2. Directly with dielectric constant.
3. Inversely with distance between plates or thickness of dielectric.

A modern capacitor tester is shown in Fig. 16-5.

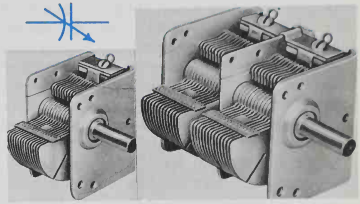


Fig. 16-6. Single and two-gang variable capacitors shown with symbol for variable capacitor.

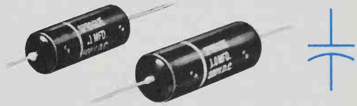


Fig. 16-7. Molded paper capacitors shown with symbol for fixed capacitor.

Fig. 16-5. Digital capacitor tester. (Dynascan Corp.)

KINDS OF CAPACITORS

Capacitors are manufactured in a wide variety of types, sizes, and values. Some are fixed in value, others are variable. In Fig. 16-6 two VARIABLE CAPACITORS are illustrated. These types are used in tuning circuits of radios as well as other circuits. Note the symbol for a variable capacitor. The fixed plates are called the STATOR and the rotating plates are called the ROTOR. The insulation or dielectric is AIR. The next time you turn the knob on your radio to your favorite station, you will be turning the rotor of a variable capacitor in the radio circuit.

A common type of FIXED CAPACITOR consists of two layers of metal foil separated by waxed paper. This is rolled up into a cylinder and usually encapsulated in plastic. Refer to Fig. 16-7. Wire leads connected to the foil plates form the external connections to the capacitor. This type is called a "paper capacitor." The plastic coated types are rigid, less fragile, and can be used at higher temperatures.

Another group you should recognize are the CERAMIC CAPACITORS illustrated in Fig. 16-8. These discs are made by using ceramic as an insulator and a silver deposit on each side for the plates. These are used for small values of capacitance and an ordinary TV set might contain several dozen in its circuitry.

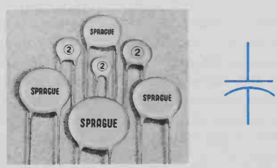


Fig. 16-8. Ceramic capacitors.

A very important group of capacitors will be the ELECTROLYTIC TYPES. These are needed when a relatively large amount of capacitance is needed in a small space. They are formed by chemical action. The dielectric is a very thin coating of oxide on the inside of a metal container. You will find these metal cans in paper containers and also the can type as shown in Fig. 16-9. Note that some cans may contain two or more capacitors. One particular point you must always remember about the electrolytic capacitor is that one end is positive (+) and the other negative (−). You must always observe this polarity when connecting in your circuit. The symbol on a drawing will have positive and negative marks. These polarity marks will tell you it is an electrolytic.

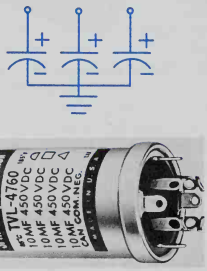


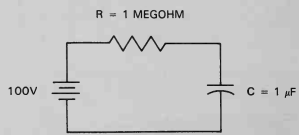
Fig. 16-9. Electrolytic capacitor and symbol.

RC TIME CONSTANTS

Earlier in this unit the time required to charge a capacitor was discussed. If there is resistance in series with the capacitor, the charging time period can be extended because the resistor limits the current flow. The time required to charge a capacitor to about 63 percent of maximum voltage in an RC circuit is the TIME CONSTANT of the circuit. It may be found by the formula:

time in seconds = R in ohms × C in Farads

Again, it is agreed that 5 time constant periods are required to charge the capacitor. In Fig. 16-10 an RC circuit is drawn and the time constant computed. This circuit has a time constant of one second. Five seconds are required for C to become charged.



TIME CONSTANT = $(1 \times 10^6) \times (1 \times 10^{-6}) = 1$ SEC

Fig. 16-10. In this RC circuit, C will charge to about 63 volts in one second. At the end of five seconds, C will be charged to about 100 volts.

CAPACITIVE REACTANCE

In a dc circuit a capacitor charges to the value of the applied voltage and the current becomes zero. Infinity resistance also produces zero current, so we can conclude that a capacitor BLOCKS a dc current. Capacitors are used in many applications.

However, look what happens when an ac voltage is connected to the capacitor. This is illustrated in Fig. 16-11. During the positive half cycle current flows in one direction. During the negative half cycle it flows in the opposite direction. Current is always flowing in one direction or the other. How much current? That depends upon the size of the capacitor and the frequency of the applied voltage. A capacitor can be considered as an opposition to the flow of alternating current. This opposition is called CAPACITIVE REACTANCE. Its symbol is X_C. It is measured in OHMS. This particular characteristic of a capacitor can be computed by the formula:

$$X_C = \frac{1}{2\pi fC}$$

where,

X_C = capacitive reactance in OHMS.
f = frequency of applied voltage in HERTZ.
C = capacity in FARADS.

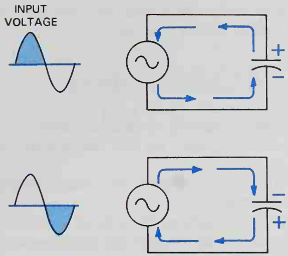


Fig. 16-11. Current flows in a capacitive circuit when an ac voltage is applied. The amount of current depends on the reactance of C in ohms.

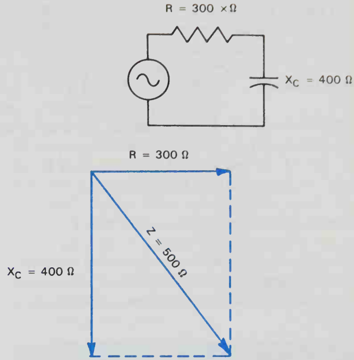


Fig. 16-12. A series RC circuit has resistance of 300 Ω and X_C of 400 Ω. Its impedance Z is 500 Ω.

IMPEDANCE

In a circuit containing both resistance and capacitance, there would be a total effect of opposition to the flow of alternating current. The total opposition of R and C cannot be added directly together since the capacitance causes the current to lead the voltage and the current and voltage in a resistor are always in phase. Therefore, a vector addition must be made to discover the resultant opposition. This resultant is called IMPEDANCE, using the letter symbol Z. It is measured in OHMS.

Refer to the diagram in Fig. 16-12 in which a vector diagram and circuit are calculated. Review the lesson on X_L and note the differences.

$$Z = \sqrt{R^2 + X_C^2}$$

Note that the X_C vector is drawn downward. The horizontal line represented by R is a reference since I and E are in phase. Therefore, X_C is 90 deg. downward showing that this voltage is 90 deg. lagging behind the resistive voltage and current. This is the same as saying the current is leading a voltage which is 90 deg. behind.

X_L and X_C

It is of extreme importance for anyone interested in electronics to gain a thorough understanding of the values of X_L and X_C when the frequency of an applied voltage is changed. Compare the two graphs in Fig. 16-13 and make these conclusions.

X_L increases in ohms with higher frequency.
X_C decreases in ohms with higher frequency.
At zero frequency or dc:

X_L = zero ohms
X_C = infinity ohms

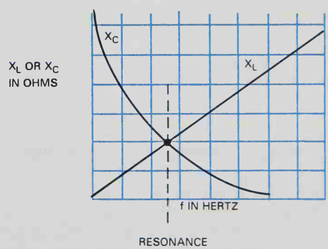


Fig. 16-13. On the graph is plotted the value in ohms of X_C and X_L as frequency is increased from zero frequency or dc. RESONANCE is the frequency where X_L and X_C cross and become equal in value.

At high frequencies:
X_L increases linearly
X_C approaches zero ohms

RESONANCE

RESONANCE is when X_L equals X_C. In a circuit containing R, L, and C, as is apparent in Fig. 16-13, at one single frequency X_L is equal to X_C. At this point X_L cancels X_C since they are 180 deg. opposite to each other. The impedance of the circuit is equal to only R,

$$Z = R$$

The particular frequency at which this occurs is known as the RESONANT FREQUENCY of the circuit. Mathematically, the resonant frequency equals:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

when,

f_r = resonant frequency.
π = 3.14
L = Inductance in henrys.
C = Capacitance in farads.

Your more advanced studies will show how resonant circuits play a major role in radio communications, television, and thousands of other electronic applications. At this point you will start to make electronics perform for you to make some amazing projects.

QUIZ — UNIT 16

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. What is the unit of measurement of capacitance?
2. Draw the symbol for a fixed capacitor.
3. Draw the symbol for a variable capacitor.
4. Electrons (repel) (attract) each other.
5. When selecting a capacitor, what else should you consider besides its value in farads?
6. Variable capacitors used in radio turning circuits have fixed plates called the ________ and rotating plates called the ________. The insulation or dielectric is ________.
7. What is the name of the common type of fixed capacitor that consists of a roll of two layers of metal foil separated by waxed paper?
8. What term is used to describe the opposition to alternating current flow through a capacitor?
9. X_C is a symbol for what property of an electronic circuit?

Unit 17

SEMICONDUCTORS AND INTEGRATED CIRCUITS

After studying this unit, you will be able to answer these questions:

1. **What is a solid state device?**
2. **What is a solid state diode?**
3. **How does a transistor amplify a signal?**
4. **What is an integrated circuit?**

The transistor was invented in 1948. This tiny electronic component has revolutionized the electronic industry. It has paved the way for unbelievable miniaturization of circuitry and equipment. The transistor will be found in our space ships as well as in sophisticated computers. Is it any wonder that you are encouraged to study the transistor?

AMPLIFICATION

In 1906 a new invention appeared on the American scene. It was the AUDION, invented by a famous American scientist, Dr. Lee DeForest. This was a three element vacuum tube which could perform as an AMPLIFIER, a DETECTOR of radio waves and a GENERATOR of Radio Frequency Waves. This date marks the birth of radio technology.

The ability of a component or device to increase the magnitude of an almost infinitely small audio or radio signal wave is called AMPLIFICATION. The ability of a vacuum tube, and more recently the transistor, to amplify is an outstanding contribution to electronic technology and is directly responsible for the spectacular growth of the industry.

Fig. 17-1 illustrates the meaning of amplification. A small signal (ac wave) is introduced to the input of the amplifier. The output wave from the amplifier is increased in size or amplitude. A signal can be amplified several times until the amplitude is satisfactory for a particular application.

It is important to understand that the power of the output wave of an amplifier comes from a local power source in the amplifier. The input signal is the DRIVING SIGNAL which causes the amplifier to produce the output signal.

Before we study the transistor and its ability to amplify, an introduction to semiconductor or "solid state" devices should be quite meaningful.

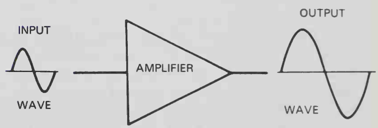


Fig. 17-1. An amplifier increases the amplitude of a signal. The triangle is the accepted symbol for an amplifier.

SEMICONDUCTOR CURRENT FLOW

In earlier studies we discovered that an electric current may be explained as the transfer of energy along a conductor by ELECTRON movement. This statement must be revised to explain conduction in some types of semiconductors. In some materials, current carriers will be HOLES which have a positive charge which will attract electrons. The diagrams in Fig. 17-2 will

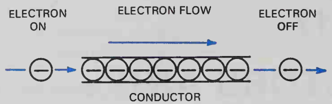


Fig. 17-2. As an electron is forced on one end of a conductor, an electron is forced off the opposite end. Energy is transferred by electrons.

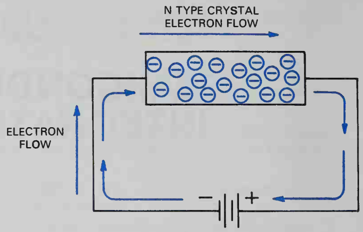


Fig. 17-4. Current flows through the N type crystal by movement of electrons.

explain electron movement and Fig. 17-3 will explain "hole" movement. Current flow in a transistor may be either electrons or holes depending on the type of material.

N TYPE CRYSTALS

The base materials used for semiconductors are SILICON and GERMANIUM which have been DOPED with a minute quantity of an impurity. Arsenic and antimony are PENTAVALENTS (five electrons in outer orbit) and when added to germanium the number of free electrons is increased. It becomes an N type crystal and conduction through the crystal is by "negative electrons," Fig. 17-4.

P TYPE CRYSTALS

On the other hand, if the base crystal is doped with a TRIVALENT impurity such as aluminum, gallium, or indium, an excess of "holes" or positive sites is created and conduction through the crystal will be by positive hole carriers. Refer to Fig. 17-5. This type of crystal will be called a P crystal.

DIODES

When an N and a P crystal are joined or grown together, a DIODE is created. Diodes may be used to block current in one direction and to pass current in the other direction. The symbol for a diode is shown in Fig. 17-6.

SEMICONDUCTOR FORWARD BIAS

In Fig. 17-7 the external battery is connected so that the NEGATIVE BATTERY TERMINAL is connected to the N crystal and the POSITIVE BATTERY TERMINAL is connected to the P crystal. This is FORWARD BIAS and current will flow in the circuit. Electrons leaving the source will flow to the N crystal and conduction through the N crystal will be by electrons. At the junction, electrons will diffuse across the junction to fill the holes in the P crystal. At the positive terminal, electrons will be drawn from

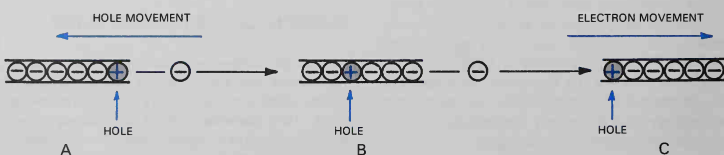


Fig. 17-3. An electron leaving the conductor produces a hole (A) which is filled by the next electron. The hole moves along the conductor (B) until it is filled by an electron from the source (C).

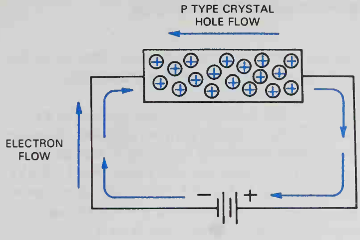


Fig. 17-5. Current flows through the P type crystal by movement of "holes." Current in external circuit is electron flow.

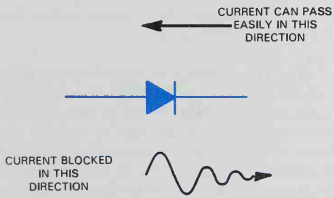


Fig. 17-6. Diode symbol.

the P crystal and attracted to the positive battery terminal. When an electron leaves the P crystal a hole is created. Holes drift toward the junction where they are filled with electrons.

SEMICONDUCTOR REVERSE BIAS

In Fig. 17-8 the external voltage is reversed. The NEGATIVE BATTERY TERMINAL is connected to the P crystal; the POSITIVE BATTERY TERMINAL is connected to the N crystal. This is REVERSE BIAS for the diode. Electrons in the N crystal are attracted toward the positive battery potential. Holes in the P crystal are attracted toward the negative battery potential. As a result, electrons and holes do not have an opportunity to meet and join at the junction. Very little current will flow in the circuit. A diode is a ONE DIRECTION ONLY conductor. It is represented by schematic symbols in both Figs. 17-7 and 17-8 with appropriate battery connections.

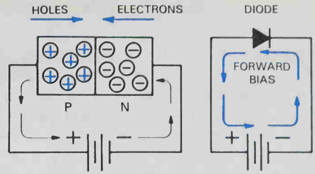


Fig. 17-7. The diode in a FORWARD BIAS connection. The P crystal carries current by HOLES. The N crystal carries current by ELECTRONS. Current in external circuit is electron flow.

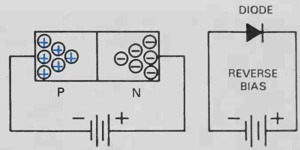


Fig. 17-8. Current does not flow in the REVERSE BIAS connection. Holes and electrons do not meet at the junction.

LIGHT EMITTING DIODES

The light emitting diode (LED) is a special diode that will give off light when the correct voltage is applied to the P-N junction. The symbol and pin connection diagram are shown in Fig. 17-9.

As electrons travel in forward bias through the P-N junction in a LED, the energy given off

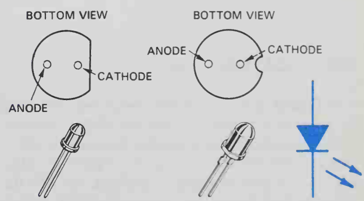


Fig. 17-9. Pin diagrams and symbol for light emitting diodes (LED).

is in the form of light. Light emitting diodes can produce light in various colors such as red, green, yellow, and infrared. They are very inexpensive, easy to manufacture, and have extremely long life. Another advantage is that they can be turned on very quickly (a few billionths of a second) as compared to a filament lamp. They operate from very low voltage and currents in the circuit. See Fig. 17-10 for some LED's which are molded into a small case for mounting into a panel.

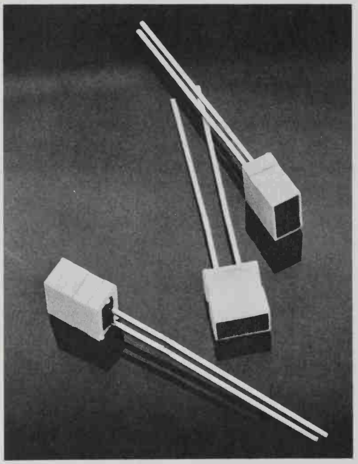


Fig. 17-10. Light emitting diodes in molded cases. (Monsanto Corp.)

RECTIFICATION

A DIODE is a very useful component when it is necessary to convert an alternating current into a pulsating direct current. The simple HALF WAVE RECTIFIER circuit is drawn in Fig. 17-11. When the input voltage is on its positive half cycle, the diode conducts and a voltage appears across the load resistor. During the negative half cycle the diode is reverse biased and does not conduct. The pulsating voltage across the load R is illustrated.

Since only half of the wave is used in a half-wave circuit, more efficient power supplies have been developed to use both halves of the cycle. These circuits are called FULL WAVE RECTIFIERS. In Fig. 17-12, a full wave power supply shows the path of current in the secondary of the transformer from A to B.

During the next half cycle, the current reverses direction in the primary and secondary of T_1. See Fig. 17-13. Now the current flows from C to B in secondary. Note, however, that the current still flows in the same upward direction through resistor R_1. Thus the ac has been changed to pulsating dc.

A FILTER consisting of capacitors and inductors connected to the output of the rectifier will remove the pulsations in the dc and result in a constant dc voltage suitable to operate electronic circuits. A complete power supply circuit is presented in Fig. 17-14 for your inspection. It uses a transformer to step-down the ac input voltage. Two diodes are used in the circuit for full wave rectification. Resistors and capacitors are used for filters. R_2 is a bleeder resistor which allows the capacitors to discharge when the power supply is turned off. This is a SAFETY feature.

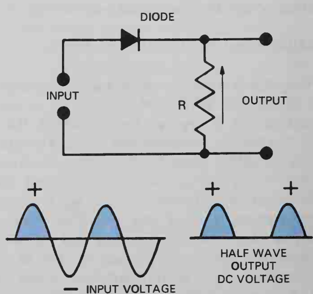


Fig. 17-11. A diode converts an alternating current voltage to a pulsating dc voltage. Diode conducts only during the positive cycle of the input wave.

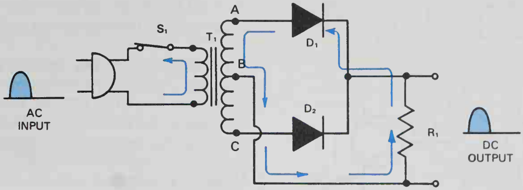


Fig. 17-12. Full wave rectifier current flow.

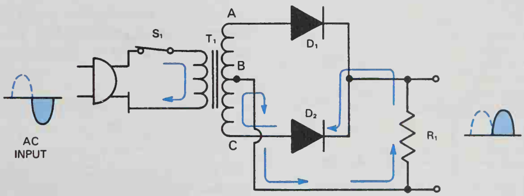


Fig. 17-13. Opposite current flow for full wave rectifier.

THE TRANSISTOR

The TRANSISTOR is formed with three crystals in sandwich-like arrangement of two diodes back to back. In one form an N type material is between two P type materials. This is a PNP transistor. If P type material is between two N type materials, it is a NPN transistor. Both types of transistors are illustrated by block diagrams with their schematic symbols in Fig. 17-15. Note that connections are made to the crystals and marked E for EMITTER, B for BASE, and C for COLLECTOR. The base is the center element between the emitter and collector.

TRANSISTOR CIRCUITS

Three methods may be used in connecting a transistor amplifier. Each method has its own individual characteristics. In Fig. 17-16 the CB (common base), CE (common emitter), and CC (common collector) circuits are drawn schematically using the NPN transistor. A PNP transistor could be used by reversing the polarities of the batteries. In any event, the emitter-base junction is forward biased and the collector-base junction is reverse biased. In the CB circuit the input signal is connected between the emitter and BASE; the output is taken from the collector and BASE. The BASE is common to both input and output circuits.

In the CE circuit, the input signal is applied to the base and EMITTER; the output is taken

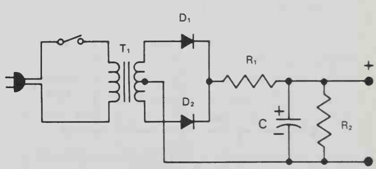


Fig. 17-14. A simple power supply circuit. Notice transformer, full wave rectifier, filter, and bleeder resistor. Output is constant dc.

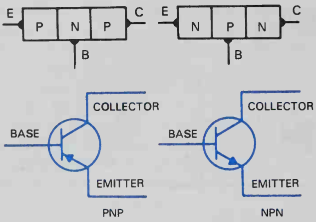


Fig. 17-15. The block diagrams and schematic symbols for the PNP and the NPN transistor. Note collector, base, and emitter designations.

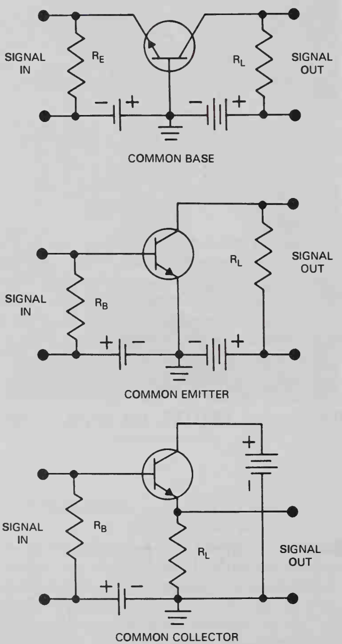


Fig. 17-16. The schematic diagrams for the CB, CE, and CC transistor circuits.

from the collector and EMITTER. The EMITTER is common to both input and output circuits.

In the CC circuit, the signal is applied to the base and COLLECTOR; the output is taken from the emitter and COLLECTOR. The COLLECTOR is common for both input and output circuits. Note that the collector is not at dc ground. The collector is usually grounded for SIGNAL purposes by a capacitor with low reactance connected to the collector. The emitter is isolated from the collector by the load resistor.

THE TRANSISTOR AMPLIFIER

How a transistor amplifies may be understood by examining Fig. 17-17. The input current is marked I_E. This current is carried

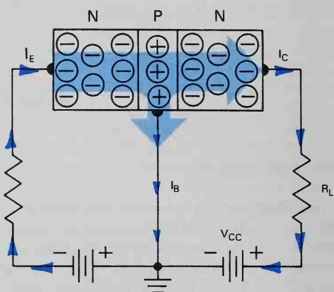


Fig. 17-17. CURRENT flow through the transistor. Only a small fraction of the current flows in the base circuit.

through the emitter section by electrons (in the NPN type). At the emitter-base junction electrons combine with the holes in the base section. The emitter-base junction is forward biased. But the base section is very thin and many more electrons enter the base section than can be combined with the holes. These many electrons feel the influence of the higher voltage applied to the collector and flow across the base-collector junction through the collector section and onward to the positive voltage source, V_{CC}. In fact, only about one or two per-

cent of the total current, I_E, will flow in the base circuit as I_B. The remaining 98 to 99 percent will flow to the collector circuit as I_C. The current I_C will produce a voltage drop across R_L which will be the output of the amplifier.

The relationship would appear as,

$$I_E = I_B + I_C$$

and I_C must always be less than I_E by a small amount. The relationship between I_C and I_E is called ALPHA (α) and means the current gain of the common base transistor circuit. A relatively small voltage is required at the input to increase I_E. Most of this current becomes I_C and produces a larger voltage across the larger resistance R_L. In this manner, a large gain in voltage can be realized. Current gain will be less 1.

THE COMMON EMITTER CIRCUIT AND BETA

When the transistor is connected in the common emitter circuit, we will find that the ALPHA current gain is still useful. An example will illustrate this point. Assume in Fig. 17-18 that 10 mA is flowing in I_E. Two percent or .2 mA is flowing as I_B and the remainder 9.8 mA is I_C. This tells us that there is a relationship between I_C and I_B. This relationship is called BETA (β):

$$\beta = \frac{I_C}{I\beta}$$

or

$$\frac{9.8 \text{ mA}}{.2 \text{ mA}} = 49$$

Beta is the current gain of the common emitter circuit. Within the operating range of the transistor, if I_B changes a small amount, then I_C will change Beta times as much or $\beta \times I_B = I_C$. In this manner the CE circuit will produce a CURRENT GAIN. It will also produce a VOLTAGE GAIN as I_C flows through R_C. Remember only a small voltage at the input will cause an increase in I_B.

This brief description of transistor theory is an introduction to the very fascinating field of solid state electronics. It should encourage you to continue your studies and discover the many

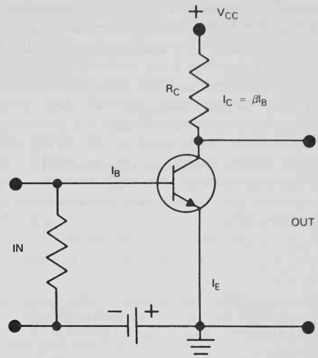


Fig. 17-18. In the CE circuit a small increase in I_B produces a large change in I_C.

and varied applications of transistors in electronic equipment.

INTEGRATED CIRCUITS

After the invention of the transistor in 1948, technology developed to add multiple components such as diodes, transistors, and resistors, to a single material called a substrate. This process was referred to as "integrating" the circuit with many components into one package. Thus the name of INTEGRATED CIRCUIT or IC was coined and the MICROELECTRONICS age began.

Integrated circuits have an advantage over individual discrete components in that many components can be packaged into a very small area. The classification scheme for integrating transistors onto a single chip or substrate from small scale integration to very large scale integration is shown in Fig. 17-19. This substitution of microelectronic devices for discrete components greatly reduces costs of the IC's.

Microelectronics has created the capability of extending our intellectual power. One of the primary uses of the integrated circuit is in computers. The MICROPROCESSOR INTEGRATED

CIRCUIT is the heart of a mini-computer. A MICROPROCESSOR is the central arithmetic and logic unit of a computer along with the associated circuitry. Tens of thousands of components are integrated into a single silicon chip to make the microprocessor IC. Fig. 17-20 shows a microprocessor integrated circuit that is functionally equivalent to 25 off-the-shelf IC's. A typical desktop computer with a color monitor is shown in Fig. 17-21. This microcomputer utilizes integrated circuits in the circuits.

Fig. 17-21. Desktop computer. (Hewlett-Packard).

TYPE OF INTEGRATION	APPROPRIATE NUMBER OF TRANSISTORS PER CHIP
(SSI) Small Scale Integration	Up to 10
(MSI) Medium Scale Integration	Up to 100
(LSI) Large Scale Integration	10,000-20,000
(VLSI) Very Large Scale Integration	100,000 or More

Fig. 17-19. Classifications of types of integrated circuits.

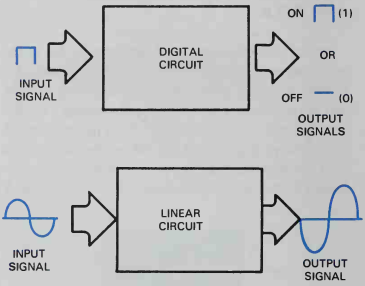


Fig. 17-22. Digital and linear circuits compared.

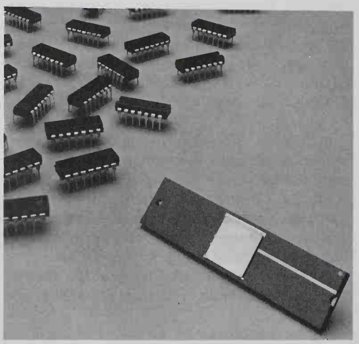


Fig. 17-20. Microprocessor I C in foreground that is the equivalent of the 25 off-the-shelf IC's shown.

DIGITAL VS LINEAR INTEGRATED CIRCUITS

Integrated circuits may be classified into two major types: LINEAR and DIGITAL. A DIGITAL CIRCUIT is either on or off depending on the input. Usually a large number of digital circuits are needed to process information such as in calculation and computers.

LINEAR INTEGRATED CIRCUITS, on the other hand, require amplification of the input

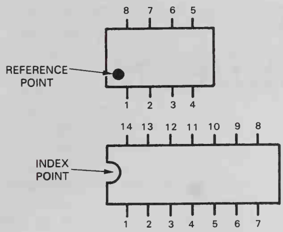


Fig. 17-23. Basing diagrams for IC's.

signal. There is always an output, whatever value, when there is an input. The input is variable depending on the input, not just on or off as in digital IC's. Sometimes amplification is referred to as GAIN. Also linear integrated circuits are sometimes called ANALOG, however, the term linear is preferred. (See Fig. 17-22.)

BASING DIAGRAMS FOR IC'S

Fig. 17-23 shows a typical basing diagram for two common types of integrated circuits. Note that the index or reference point is the starting location for the numbers and the pins are numbered in a reverse "C" direction.

QUIZ — UNIT 17

Write your answers to these questions on separate sheet of paper. Do NOT write in this book.

1. Three methods may be used in connecting a transistor amplifier. They are common ________, common ________, and common ________.
2. When the transistor is connected in the common emitter circuit, we will find that the ________ current gain is still useful.
3. The ability of a component or device to increase the magnitude of an almost infinitely small audio or radio signal wave is called ________.
4. A ________ is a useful component when it is necessary to convert an ________ current into a pulsating ________ current.
5. The transistor is formed with ________ ________ in sandwich-like arrangement.
6. Dr. Lee DeForest invented the Audion. This was a three element vacuum tube which could perform as an ________ a ________ of radio waves and a ________ of radio frequency waves.
7. What is amplitude?
8. Give three advantages for a light emitting diode: ________ ________ ________
9. In the waveform below, the type of electrical signal is called ________ ________ direct current.

10. Integrated circuits can be classified into two types which are ________ and ________.

Unit 18

ELECTRICAL PROJECTS

CONSTRUCTION PRACTICE

The suggested projects described on the following pages are intended to demonstrate some of the electrical principles you have studied in the Units of this book.

Before you proceed with the project, turn to page 4 and review all of the safety procedures.

The projects are not arranged in order of difficulty, and it is unnecessary to follow a prescribed order.

Exact specifications, in respect to size and kinds of material used in these projects have been purposely omitted, thus leaving it to the judgment and desire of the student to adapt and use materials readily obtainable. For example, a buzzer might be constructed on a wood or plastic base. The base might be 3 × 4 or 4 × 6 inches. The exact size is unimportant.

Whatever materials are selected, you should make every effort to develop skills in the use of hand tools so that your projects are well made projects. A little care in sanding and finishing a wood base will help produce a project that is worthwhile and one of which you may be proud. A good worker is always developing habits which show good results.

Experience suggests a few hints and kinks which will be useful to you in your work.

1. When making a core for an electromagnet, it is important to remember that a low carbon or mild steel should be used. This type of steel does not retain its magnetism. Nails and stove bolts of various sizes make excellent core materials.
2. Wrap the iron core with a layer of friction tape before you start to wind the coil, thus insulating the windings from the core and also providing a good base on which to wind the coil.
3. Insulated wire, either enamel or cotton covered, should be used for coil winding.
4. Remember that when soldering the ends of enamel covered wire, the enamel must first be removed. Scrape it off with a knife or remove it with fine abrasive paper.
5. In some projects it is necessary to solder a small piece of iron to a brass or copper armature. This is best accomplished by using a method called SWEAT SOLDERING. Do not use a soldering gun for this operation. It does not get hot enough.

To sweat solder two pieces together, first coat each piece with a thin layer of solder. This is called tinning. Place the two pieces together in the desired position and apply pressure by means of a short piece of metal rod. While holding the pieces together apply heat by means of a soldering torch or a soldering iron. When the solder melts between the two pieces, remove the heat but hold firmly in place until the solder sets hard. Observe method in Fig. 18-1.

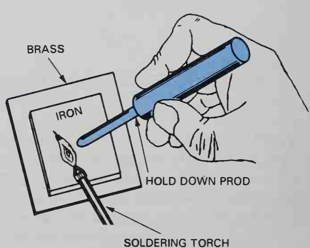


Fig. 18-1. While sweat soldering, pressure is applied to the iron by the hold down prod while heat is applied.

6. When winding coils, always keep the wire tight and wind it close, even coils and layers. A suggested method of starting and ending coils is shown in Fig. 18-2. A small hole is first drilled in the fiber washer near the core. The starting end is put through the hole, and extended enough to provide a connection to the coil. When the coil is wound, the finished end is placed through a second small hole in the washer coil end. This holds the coil firmly in place.

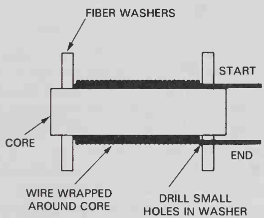


Fig. 18-2. The ends of the coil are inserted in small holes in the fiber washer.

7. The springs used in the projects may be made by winding the correct size of music wire or spring brass wire tightly around a form of the correct size. You will need to experiment some to get the right spring tension.
8. When making a solenoid sucking coil, it should be wound on a hollow core of some non-magnetic material such as copper, brass, aluminum, plastic, fiber wood or cardboard.
9. Finished coils may be varnished or lacquered to hold the wires in place and give an attractive appearance. Some coils may be wrapped with plastic tape.
10. Exposed wires in the projects may be covered with a tubular type of insulation known as spaghetti. Cut the correct length and slip it over the wire leads.
11. Metal brackets and coil supports are made easily from soft metals, such as aluminum, copper, and brass. Use iron when specified in the plans.
12. Before starting a project, some planning should be done and a sketch made. Show your plans to your instructor, who may give you some helpful suggestions and avoid later difficulties.
13. Your completed project should include:
    a. Sketch of project with schematic.
    b. A parts list.
    c. Actual working project.
    d. Completed answers to questions on "why it works."
    e. List of several industrial or commercial applications of the electrical principles demonstrated by your project.
14. Always use a low wattage soldering pencil (25-40 watts), when soldering transistors and diodes.
15. Be sure to use a heat sink on temperature sensitive component leads such as transistors and diodes.
16. It is always a good idea to use sockets for integrated circuits.

PROJECT 1 EXPERIMENTER

The Experimenter is a valuable electronic tool to use in learning more about how circuits work. (See Fig. 18-3.) It has a 5 volt dc power supply; an experimenter socket for wiring circuits, and four switches (2 SPST and 2 SPDT). Resistors, incandescent lamps, LED's, diodes, transistors, capacitors, and other components can be plugged into the socket for tests and experimental circuits. Also, parallel and combination circuits can be connected using the Experimenter.

CONSTRUCTION HINTS

1. Obtain parts and wire the 5 volt dc power supply. See Fig. 18-4 for the schematic.

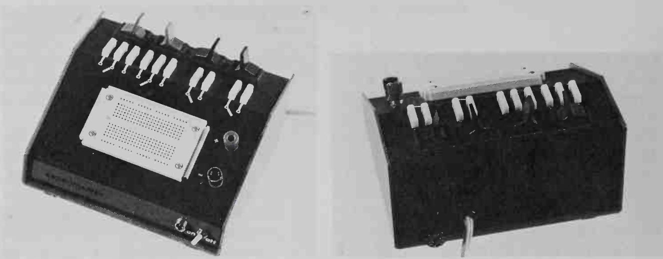


Fig. 18-3. Front view of Experimenter.

The line cord should enter the chassis in the back through a rubber grommet. Also, the fuse is mounted in a fuse holder. The toggle switch for the power supply is mounted on the front panel.

2. Mount the two single pole, single throw (SPST) switches and the two single pole, double throw (SPDT) switches on the top of the front panel. Next mount the four tie point block solderless connectors on the chassis (be sure that the pins under the solderless connectors do not short out on the metal chassis). Then wire the switch leads to the four pin solderless connectors.
3. Mount the experimenter socket on the front panel of the Experimenter.
4. Mount the power supply to front panel. Be careful that exposed wiring does not touch metal for shorts. Also be sure 5-way binding posts do not short out on the metal chassis.

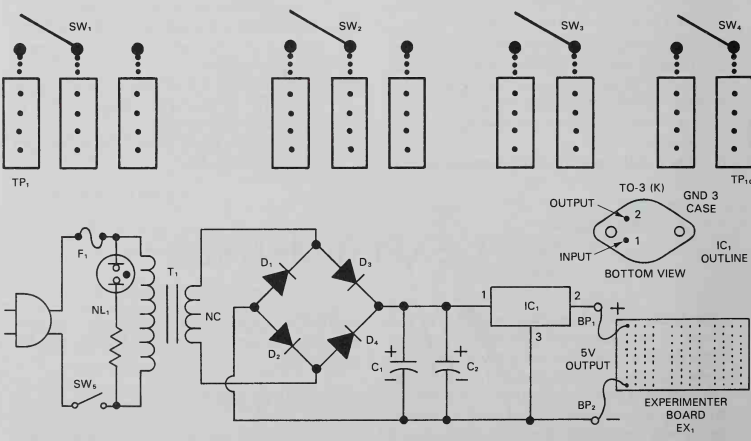


Fig. 18-4. Schematic and parts list for the Experimenter.

PARTS LIST FOR EXPERIMENTER

SW_1 & SW_2 — Single pole, double throw (SPDT) rocker switches.
SW_3 & SW_4 — Single pole, single throw (SPST) rocker switches.
SW_5 — Single pole, single throw (SPST) miniature switch.
F_1 — Fuse holder, panel mounted.
FUSE — 2 amp, fast acting fuse.
NL_1 — Neon indicator glow lamp with built-in 100K Ω resistor, 120V ac.
T_1 — Filament transformer: primary 120V ac, secondary 6.3V ac @ 1 amp.
D_1 - D_4 — Silicon diodes, IN4001.
C_1 & C_2 — Electrolytic capacitors, 2200 MFD @ 16V dc.
IC_1 — Voltage regulator (5 volt), LM309K (National Semiconductor).
BP_1 & BP_2 — 5 way Binding Posts (one black and one red.)
EX_1 — EXPERIMENTER SOCKET - CSC, Experimentor #350.
TP_1 - TP_{10} — TIE POINT BLACK SOLDERLESS CONNECTORS (10) - AP-TB1, Post #923297.
CHASSIS — Miniature console.
MISC: — Line cord, perf-board for wiring power supply, solder lugs, rub-on decals, solder.

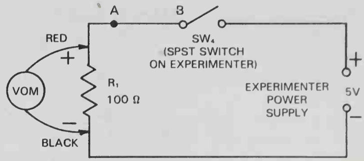
USING THE EXPERIMENTER

The Experimenter can be used to perform many experiments which can be used to reinforce theory. The following experiments are very basic and hopefully will help you to understand the concepts of electricity better. In addition to the experiments in this book, you are encouraged to design your own experiments or to use other experiments which may be provided by the instructor.

Remember, it is much safer to double check your wiring BEFORE you turn on the power for an experiment. When using meters, be sure that you have the meter on the correct range and the leads are connected with the right polarity.

PROBLEM 1: USING A VOLT METER AND AMMETER

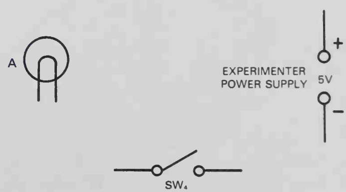
1. Obtain the following components:
   Experimenter
   Volt Ohm Meter (VOM)
   R_1 — 100 Ohm 1 Watt Resistor
   Jumper Wire
2. Connect the components as indicated in the schematic at the top of the next column: (Do not turn on power yet.)



3. Double check your wiring then turn on experimenter power supply switch, then turn on SW_4.
4. As shown in the above schematic, measure the voltage across R_1. The voltage is ______ volts.
5. Next measure the voltage across the output of the power supply. (The red and black binding posts.) The voltage is ______ volts.
6. Measure the voltage across SW_4. Why isn't there any voltage across SW_4?
7. Insert the dc ammeter in the circuit at points A and B. Be sure to break the circuit so that all the current flows through the ammeter. (Start on the highest range and come down until you get a reading.) The current is __________.
8. Turn off the power and carefully put away the components.

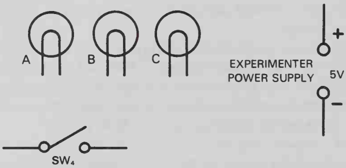
PROBLEM 2: WIRING A SIMPLE CIRCUIT WITH A LAMP

1. Obtain the following components:
   Experimenter
   Lamp A: #47 Lamp (6.3 volts @ .15 amps with 22 gauge solid jumper wire leads soldered to each base connection.)
   Jumper wire
2. Connect light A so that it may be turned on and off by switch SW_4.
3. On a separate sheet of paper, draw the complete wiring diagram below:



PROBLEM 3: WIRING LAMPS IN SERIES

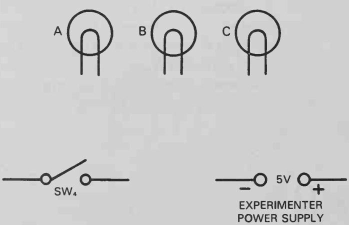
1. Obtain the following components:
   Experimenter
   Lamps A, B, and C: #47 Lamps (6.3 volts @ .15 amps with 22 gauge solid jumper wire leads soldered to each base connection.)
   Jumper Wire
2. Connect lights A, B, and C in SERIES and controlled (on and off) by SW_4.
3. On a separate sheet of paper, draw the complete diagram below:



4. Are lights brighter or dimmer than the one light used in PROBLEM 2? _________ (yes or no). EXPLAIN.

PROBLEM 4: WIRING LAMPS IN PARALLEL

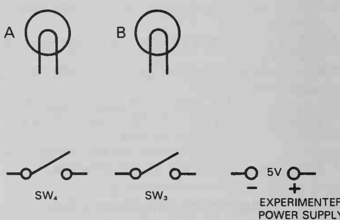
1. Obtain the following components:
   Experimenter
   Lamps A, B; and C (the same as used in PROBLEM 3.)
   Jumper Wire
2. Connect lights A, B, and C in PARALLEL and controlled by SW_4.
3. Draw the complete diagram below:



4. Are lights brighter or dimmer than the lights in PROBLEM 4? _______ (yes or no).
5. Which circuit, PROBLEM 3 or 4, is using the larger amount of electrical power? _______
6. Are electric lights in your home connected in series or parallel? _________

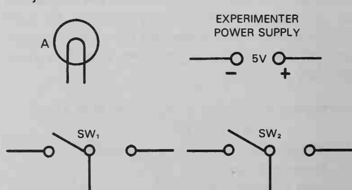
PROBLEM 5: TWO SPST SWITCH CONTROL CIRCUIT

1. Obtain the following components:
   Experimenter
   Lamps A, B, and C (the same as used in PROBLEM 3.)
   Jumper Wires
2. Connect lights A and B so that SW_4 will control light A and SW_3 will control B.
3. Draw the diagram for the complete circuit.



PROBLEM 6: WIRING A THREE-WAY SWITCH CIRCUIT

1. Obtain the following components:
   Experimenter
   Lamp A
   Jumper Wires
2. Connect light A so that it can be turned on and off by either switch SW_1 or SW_2 (three-way switch).
3. Draw the diagram below for the circuit you just wired.



4. Why are three-way switches used?
5. Name some rooms in your home in which three-way switches are used or could be used.

QUIZ — PROJECT 1

1. When lights are connected in parallel, the resistance of the circuit increases or decreases?
2. When lights are connected in series, the resistance of the circuit increases or decreases?
3. When lights are connected in series, the current in the circuit decreases or increases?
4. When lights are connected in parallel, the current in the circuit decreases or increases?
5. When lights are connected in series, if one light should burn out the others will be brighter, be dimmer, go out? Explain.
6. Lights in parallel will use more or less power than lights in series? Explain why.

PROJECT 2 STATIC BIRDS

Perhaps you have observed that if you vigorously rub a pocket comb with a cloth, it will then attract bits of paper. If you rub the fur of a kitten, you will notice the kitten's fur will stand on end as you bring your hand back over it. This was a great mystery hundreds of years ago. Materials which behave in this manner were believed to contain "dark and sinister spirits." Actually, you have displaced electrons by the friction of rubbing and the material has acquired a static charge.

HOW TO MAKE STATIC BIRDS

Secure a plastic box from your home or a store such as those used to pack candy or for flower corsages, Fig. 18-5. Almost any similar

Fig. 18-5. Static Birds in a plastic box.

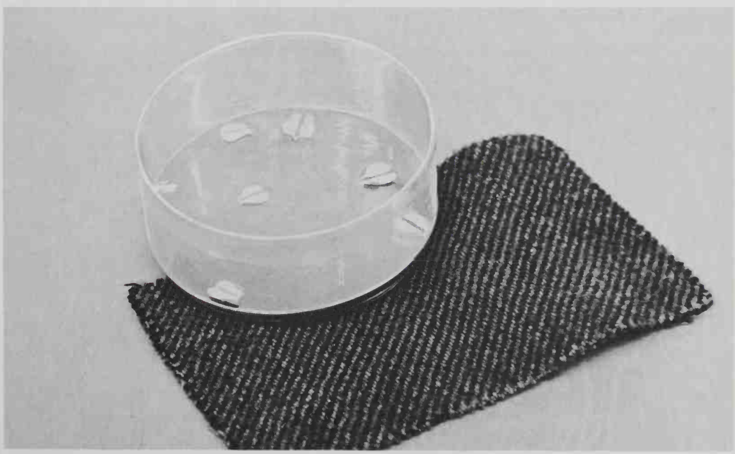


Fig. 18-6. Cut the birds out of paper, using a pattern similar to this.

box will do. Then cut some small paper birds, Fig. 18-6. Place several of these birds in your plastic box. Put the cover on and rub the box vigorously with a piece of cloth. The birds will fly around within their plastic cage.

This is an amusing project and makes a nice toy for a younger brother or sister. In this project some important electrical principles are demonstrated. First, the birds are attracted to the plastic because they have a different static charge. UNLIKE CHARGES ATTRACT EACH OTHER. When a bird touches the plastic, it then becomes charged in the same polarity as the plastic. As a result it rapidly flies away. LIKE CHARGES REPEL EACH OTHER.

Experiment by using different materials to rub the box. Select the material which produces the liveliest action. The photograph, Fig. 18-5 will give a clear picture of the construction of the Static Birds.

PROJECT 3 AUDIO OSCILLATOR

No study of electricity and electronics would be complete without reference to the transistor. In our studies we have investigated how both transistors and vacuum tubes are used in electronic circuits. The radio tube does have some disadvantages, the most important of which are its size, cost and the relatively large amount of power needed to operate it. The transistor seems to have overcome these disadvantages. It is extremely small and can be used in miniature and portable equipment. It operates with only minute power consumption. It is reliable in operation in most every kind of condition. It is low in cost and lasts almost indefinitely.

There are many applications for oscillators in electronic work. You will find this project, Audio Oscillator, Figs. 18-7 and 18-8 interesting and useful.

Fig. 18-7. Audio oscillator.

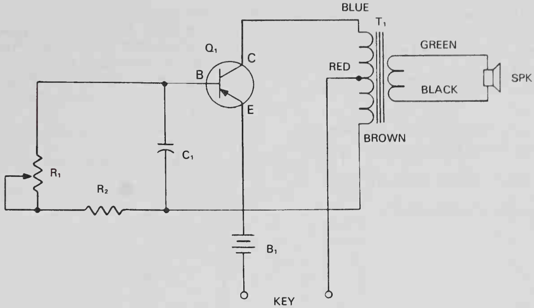


Fig. 18-8. Code oscillator schematic.

You have studied the theory of operation of a transistor. A transistor can conduct a current, or resist the flow of current, depending upon conditions under which it is operated.

In transistor circuits, a direct current voltage is applied to all three elements, the collector, the base, and the emitter. The current flowing through the base and one of the other elements can be used to control a current flowing through any other two elements. For example, the current from base to emitter can control the current flow from emitter to collector.

Students interested in the hobby of "ham radio" will find this code practice oscillator coupled with a key a useful tool while building up code speed in order to pass the FCC examination. Because this audio tone oscillator is variable in pitch, some students learn to play simple tunes on it.

CONSTRUCTION HINTS

1. The audio oscillator in the photograph in Fig. 18-7 was constructed in a plastic minibox. You may select a container of another size or material. Be sure you have enough room to easily mount all the components of your audio oscillator.

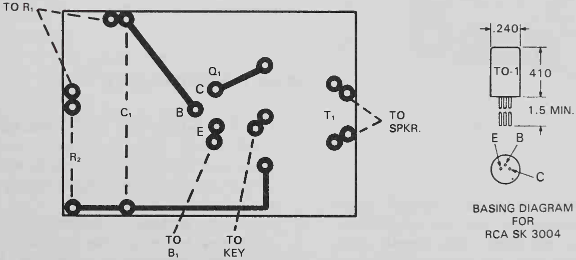


Fig. 18-9. Printed circuit layout for audio oscillator.

2. See Fig. 18-9 for printed circuit layout and transistor basing diagram.
3. The speaker used is one of the 2 inch small transistor PM speakers.
4. The oscillator is powered with a 9V transistor battery.
5. Check connections against the schematic.
6. Ask your instructor to check your work.

PARTS LIST — AUDIO OSCILLATOR

R_1 — Potentiometer, 25000 ohms
R_2 — Resistor 6800 ohms
C_1 — Capacitor .5 μF, 200 volt, paper
T_1 — Audio Output Transformer—Primary: 500 Ω to 1000 Ω C/T; Secondary: 8 Ω
Q_1 — Transistor—PNP General Purpose Transistor (Germanium) Radio Shack: RS2004, or RCA SK3004.
B_1 — 9 volt Transistor Battery
PM Speaker 2 inch, 8 Ω
Plug Jack for Key, Control Knob and Miscellaneous Hardware
Minibox Chassis — 4 3/4" × 2 1/2" × 1 2/5" with cover.

PROJECT 4 TRANSISTOR RADIO RECEIVER

Fig. 18-10. A simple transistor radio receiver.

In Project 3 you used the transistor as an oscillator. To further demonstrate the versatility of the tiny transistor, the simple radio receiver shown in Figs. 18-10 and 18-11 may be built. In this receiver, the modulated radio signal is detected by a crystal diode and the transistor is used as a stage of audio amplification.

Much of the fascination in building this radio lies in making it as small and compact as possible. It is a "vest pocket edition" of a satisfactory radio suitable for local broadcast reception.

You may experiment with the antenna. Many students use a short piece of wire and an alligator clip. The clip is fastened to most any available metal object as an antenna. The radio has worked well with the clip attached to a bicycle, a window screen, an iron table or bed spring, and so on. A ground connection improves the reception, but it works quite well without one.

CONSTRUCTION HINTS

1. The little radio in Fig. 18-10 was built in a small plastic box; however, a metal or wood box would serve equally as well. The tuning control and the earphone plug are on the front.
2. Most any battery combination up to six volts may be used. Use two to four pen light cells connected in series, Fig. 18-12. Wrap the cells up in friction tape to make a

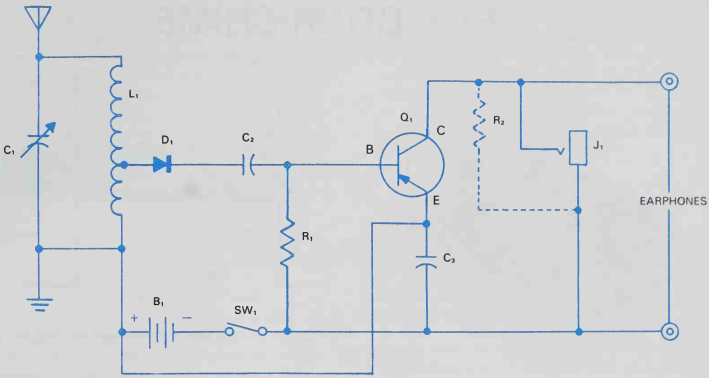


Fig. 18-11. Diode transistor radio receiver.

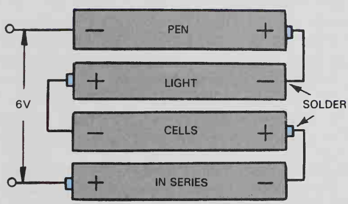


Fig. 18-12. Pen light cells connected in series.

neat bundle.

3. Wire in the usual manner, tracing your schematic with a red pencil as each connection is made.
4. Ask your instructor to inspect your wiring.
5. Connect long antenna to the radio, turn on the switch, and tune C_1 until a station is heard.

PARTS LIST — DIODE — TRANSISTOR RADIO

L_1 — Antenna Coil, Loopstick with center tap
C_1 — Variable Capacitor, 365 pF
C_2 — Capacitor, DISC .02 μF
C_3 — Capacitor, Paper, .1 μF
R_1 — Resistor 470K ohms
R_2 — Resistor 1500 ohms
(Note: Use R_2 if crystal earphone is used. Not needed if magnetic earphone is used.)
CRYSTAL Earphone, 2000 Ω
Phone Tip Jacks
Switch — SPST, Push button or miniature toggle
B_1 — two 1.5 volt pen cells in series
Antenna & Ground Terminals
D_1 — DIODE 1N34
Q_1 — PNP, 2N107, or RCA SK3003, or Radio Shack RS2004.
J_1 — Jack (optional for phone tip jacks)
TUNING KNOB — Miscellaneous Hardware

PROJECT 5 DOOR CHIME

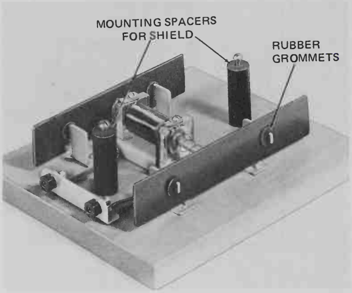


Fig. 18-13. The completed double action DOOR CHIME. You are encouraged to use an original design.

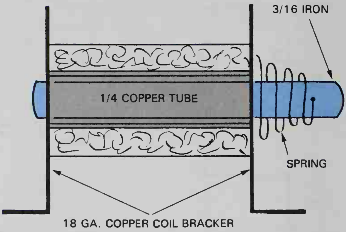


Fig. 18-14. Coil construction of two tone door chime.

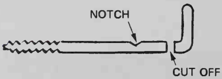


Fig. 18-15. One method of making a pin to support a chime tube or bar.

An application of the solenoid coil is the familiar door chime. The chime illustrated in Fig. 18-13 is a double chime and does require more mechanical work than a simple single chime. It is well worth the extra effort. If a good job is done, this chime will be nice enough to use in your home.

An added principle of mechanical motion is used in this project. When the coil is energized, the plunger is sucked into the coil and strikes one chime. When the coil is de-energized, the plunger is returned to its original position by the action of the spring. The momentum of the returning plunger causes it to overshoot its "at rest" position. This overshooting permits the plunger to strike the second chime.

CONSTRUCTION HINTS

1. You will want to do some experimenting with the kinds of tubes or bars you use for your chimes. Generally a thin tube, hard drawn, will produce the most pleasant tone. The tubes or bars can be cut most any length; the longer length gives a lower or deeper tone. In Fig. 18-13 flat pieces of hard steel are used.
2. Holes have been drilled in the chime bars and rubber grommets inserted in the holes. Supports are designed to hold bars in position, but not rigidly. The coil construction is clearly explained in the illustration, Fig. 18-14. The core is 1/4 in. copper tubing and the ends or coil supports are made of 20 ga. sheet copper or plastic. The core and the end brackets are soldered or glued together.
3. Wind about four layers of insulated #22 wire for the coil.
4. The chime support pin, Fig. 18-15, is one way of hanging the chime tubes or bars. A fine wire also works well. The tubes should not be supported rigidly as this will deaden the ringing tone. They should hang straight and vertical.
5. The plunger is made of a common nail and the cone type spring is wound with #6 Music Wire. The spring is fastened to the

core by drilling a small hole and inserting one end of the spring in it.

6. Some careful adjustments in spring tension and placement of the chimes are necessary to permit the plunger to strike the chimes on both right and left movement of the plunger. While these adjustments are being made, the chimes should be hung on the wall and in a plumb position.
7. For decoration and appearance, a shield can be made of metal or plastic, to cover the working mechanism of the chimes. The shield can be polished, tooled with a design, or left plain. The shield is mounted with long screws or bolts and held in front of the chime by tubular spacers.

PROJECT 6 MAGNETIC RELAY

One of the more common applications of magnetism is found in the Relay. This, in its simple form, is nothing more than a switch operated by magnetism. It has some distinct advantages. One of major importance is its ability to operate, "turn on or off," a high voltage or a high current machine or device from a remote location. This provides a high degree of safety for working personnel. Only a small low voltage current is required to activate the coil. The magnetism of the coil operates the armature which may have large and heavy contact points for switching the high power machine. The entire relay can be enclosed for greater protection. The relay also has the capability of relatively rapid switching when required.

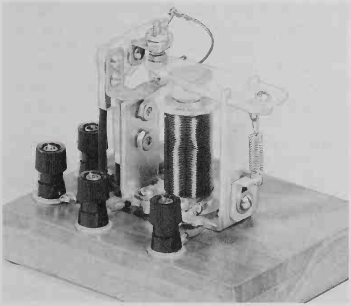


Fig. 18-16. The completed experimental relay.

CONSTRUCTION HINTS

1. Relays may be constructed in many ways. The photograph of only one kind appears in Fig. 18-16. Note that it is a single pole double throw switch. The switch contacts are connected to the three binding posts with red, green, and black wires. The relay can be used as a "Normally Closed" relay and will open the circuit when the coil is energized or a "Normally Open" relay which will close the circuit when energized. Which contacts to use will depend on its application. (See Fig. 18-17.)
2. The coil is wound with three layers of #22 enameled wire around a plastic spool. A 1/4 × 2 inch bolt is used as a core.
3. The frame of the relay is made of 16 gauge aluminum. The switch contacts are mounted on plastic for insulation and the plastic is bolted to one side of the aluminum frame.
4. The armature is also plastic and is placed on top of the opposite side of the frame. It is held down by the tension spring. A round piece of iron is cemented to the plastic armature over the core of the coil. Magnets would not attract the plastic.
5. Notice the bolts and nuts used for the contact points. Adjust the top contact to change the GAP between the coil and the armature.
6. The tension spring is also adjustable so that more or less current is required for relay operation.
7. Wires connected to the operating coil are connected to the other two binding posts.
8. A sketch of the relay is drawn in Fig. 18-18 which shows the electrical connections.

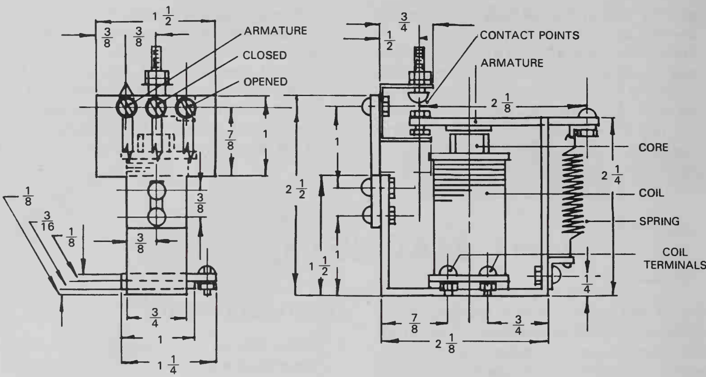


Fig. 18-17. Suggested dimension of magnetic relay.

RELAY OPERATION

1. Connect the relay operating coil to a variable (0-6 volts) voltage source. Connect voltmeter across the source and the milliameter in series with the coil as in schematic, Fig. 18-19.
2. Connect the indicating lamp to the normally closed contact points and a 6 volt power source. The light should be ON.
3. Starting with ZERO volts to relay coil, slowly increase voltage until relay operates. The indicating lamp will go "out."
4. Record the voltage and the current required to operate the relay. Volts = ______, mA = ______.
5. Return voltage to zero. Adjust tension spring so that tension is slightly increased. Repeat steps 3 and 4. Volts = ______, mA = ______.
6. Adjust upper contact point to push armature downward. This decreases the "air gap" between the coil and the armature. Repeat steps 3 and 4. Record Volts = ______, mA = ______. What effect does changing the gap have on relay operation. Explain.
7. The relay can be used to switch "on or off" any kind of a device or machine. The contact points must be heavy enough to carry the required current of the machine. In Fig. 18-20 the relay is used to switch a motor.

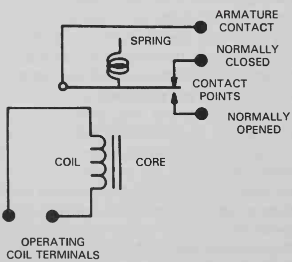


Fig. 18-18. The electrical diagram of connections to parts of the relay.

THE BUZZER OR DOORBELL

With slight changes the relay can be used as a buzzer. Connect the circuit as drawn in Fig. 18-21.

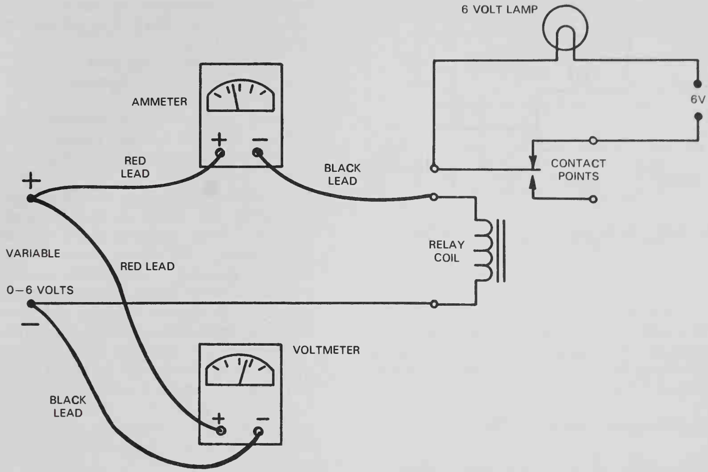


Fig. 18-19. The electrical connections for testing the operating voltage and current of the relay.

1. Connect one end of the coil to center armature.
2. Connect source voltage to the other end of coil and to the Normally Closed switch contact.

When the buzzer or doorbell push button is closed, the relay is energized which pulls down the armature and OPENS THE CIRCUIT. This allows contact points to return to CLOSED position and energizes the relay again. This opening and closing of points in rapid succession produces a BUZZ. The frequency of the buzz can be changed by adjusting the gap or the spring tension.

3. Measure and record the voltage required to run your buzzer.

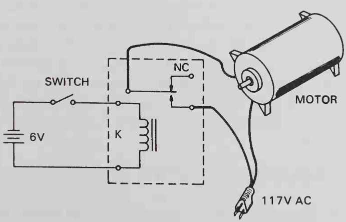


Fig. 18-20. The relay is used to remotely control a motor.

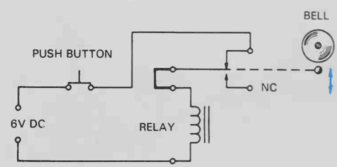


Fig. 18-21. The relay connections to make a buzzer or doorbell.

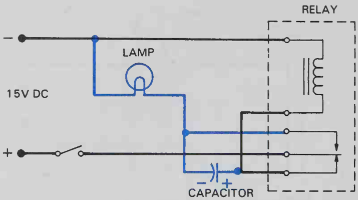


Fig. 18-22. The diagram for a mechanical oscillator using RC time constants.

If a striker is attached to the vibrating armature of the buzzer, it can be arranged to strike a bell. Now you have a doorbell. See dotted lines in Fig. 18-22.

MECHANICAL OSCILLATOR

This project is interesting since it takes advantage of the RC time constant of the circuit for operation. When proper voltage is applied to the circuit the lamp will flash.

1. Connect the mechanical oscillator circuit as described in Fig. 18-22. You will need the following extra parts.
   1 — 6V lamp and screw base
   1 — 10 μF electrolytic capacitor
   1 — SP Switch
2. Connect oscillator to a variable power source. Increase voltage gradually until lamp starts to flash (about 15 volts). Switch must be closed.
3. Using the circuit diagram trace the current flow when relay points are normally closed and open. When switch is open, a current flows through the closed points and the capacitor charges. This current is too small to light the lamp. When switch is closed, a voltage is applied to the relay coil which causes the armature to change to the other contact and the lamp will light. Now this opens the coil circuit and we would expect it to operate like a buzzer. It does not, however, since the capacitor must discharge and this discharge current flowing through the coil delays the action of the relay.
4. Remove lamp from circuit and replace with a 4 Ω speaker. Now you can hear the oscillations.

PROJECT 7 ELECTRIC PENCIL

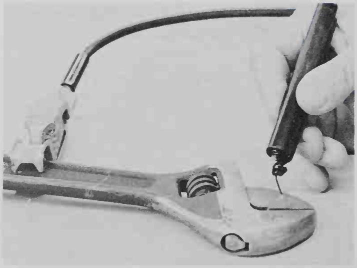


Fig. 18-23. An electric pencil may write your name or identification mark on tools and metal objects.

This is a real practical project. You will find many uses for it around the home and shop. Someone always wants to borrow your tools. By using the electric pencil, you can write your initials, name, or identifying mark on any metal tool or object. See Fig. 18-23. The power source used is a 12 volt automotive battery. One side of the battery is connected to the metal object to be marked. The other terminal of the battery is connected to the electric pencil.

CONSTRUCTION HINTS

1. The actual handle can be made of plastic or wood. It must be insulating material.
2. The banana jack is installed at the end of

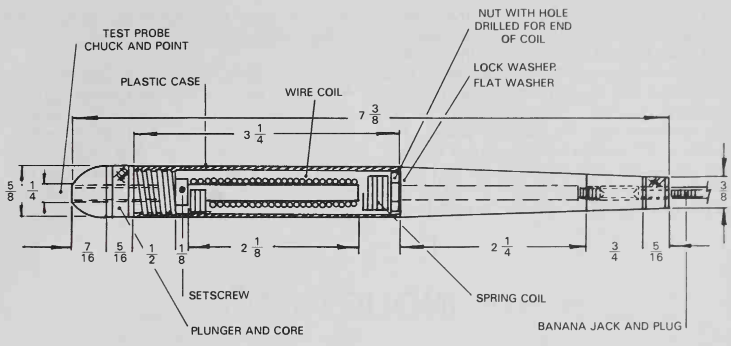


Fig. 18-24. Schematic showing construction of a practical electrical pencil.

the handle for convenient connection to lead running to the battery, Fig. 18-24.

3. The writing point can be a short piece of copper or steel wire. It is held by a small screw chuck taken from an old meter test probe.
4. The spring coil is made of #16 enameled copper wire. This coil serves a dual purpose. It makes the electrical connection between the banana jack and the sliding plunger which holds the writing point. It also is a solenoid coil which pulls the writing plunger away from the tool being marked. Its spring action returns the point to the tool.
5. The plunger at the writing end of the pencil should fit loosely so that it is free to move in and out a short distance. Note that the plunger extends partly into the coil to provide a core for the solenoid action.
6. This project, if made as illustrated in Fig. 18-25, can be an excellent lathe project involving aluminum, plastic, and soft iron.

CIRCUIT ACTION

The electric pencil is an excellent learning activity and provides experience with several electrical principles. Note that the "tool to be marked" is connected to one terminal of the battery power source. The pencil is connected to the other terminal.

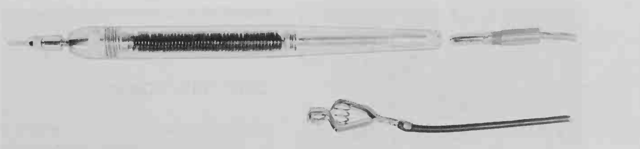


Fig. 18-25. The completed electric pencil. Use available materials and your own design.

When the writing point touches the "tool to be marked," it completes the circuit and current flows through the wire coil in the pencil. A solenoid sucking action is created which pulls the plunger into the pencil and away from the "tool to be marked." This action opens the circuit and removes the sucking action. The spring of the coil forces the plunger outward and the writing point contacts the tool again. The writing tool should vibrate on the surface of the tool. Each time the point is pulled away from the tool a small but extremely hot spark results which etches into the metal.

A little practice is required to write smoothly. If the point sticks to the tool, remove it quickly or disconnect the pencil. Your skill in using the pencil is similar to that of an electric welder. You must "strike an arc" and hold it. CAUTION: After a few minutes of writing your pencil will become warm. Let it cool! Take your time!

PROJECT 8 INDUCTION COIL

A project which has educational value is the induction coil, Fig. 18-26. Coils of this nature are widely used. One of the more common applications is the ignition coil in your automobile.

The principle of transformer action is well demonstrated in this project. You should study Unit 14 on Transformers so that you will gain knowledge about the action of this circuit.

If a varying current is flowing through a coil, there will be an ever changing magnetic field about the coil. The magnetic field will rise and fall in step with the magnitude of the current.

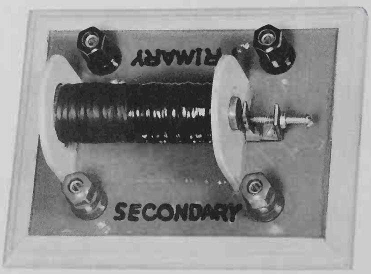


Fig. 18-26. An induction coil.

If a second coil is placed near the first coil, so this varying magnetic field will cut across it, a voltage will be INDUCED in the second coil. The first coil is called the PRIMARY. The second coil the SECONDARY. The voltage induced in the secondary is in direct proportion to the TURNS RATIO. For example: Ten turns on the primary and one hundred turns on the secondary will produce ten volts across the secondary to every one volt applied to the primary.

In our project six volts are applied to the primary. The output voltage will depend on the number of turns you use.

Actually the induction coil, without the secondary, is just another buzzer. The buzzer action is necessary to cause the rise and fall of current through the primary. Without this changing current there can be no transformer action.

When the induction coil is operating, a small spark can be made to jump across a gap between wires connected to the secondary. CAUTION: Were you to hold the secondary wires in your hands, you would get a surprising shock!

CONSTRUCTION HINTS

1. The induction coil illustrated in Fig. 18-26 has a plastic base. You may use wood if you wish.
2. The core is made of 1/16 in. welding rod cut to 6 in. lengths, grouped together and

wrapped with tape to form a round core.

3. The coil ends can be either wood or plastic. A hold the size of the core is drilled in each end. The ends are cemented in place on the core. Fig. 18-27.
4. The primary winding consists of two layers of #18 enamel covered wire. Wind neatly and then cover with another layer of tape. Leave about 6 in. of wire at each end of the coil for later connections.
5. The secondary is wound with several layers of #26 enamel covered wire. The greater number of turns will produce a higher induced voltage. Again leave sufficient wire at the end of the coil for later connections.
6. The construction of the armature and points is illustrated in Figs. 18-28 and 18-29.

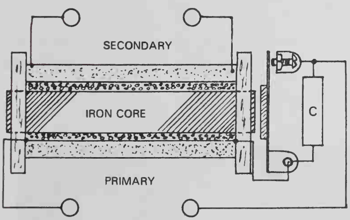


Fig. 18-27. Construction plan for the induction coil.

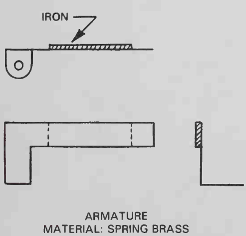


Fig. 18-28. Detailed plan for induction coil armature.

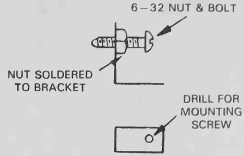


Fig. 18-29. Detailed plan for induction coil contact points.

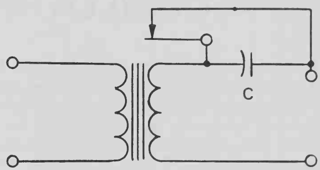


Fig. 18-30. Schematic diagram of the induction coil circuit.

7. Wiring instructions can be found by tracing the schematic drawing in Fig. 18-30.

A new component has been added to this circuit which requires some explanation. This is the capacitor, C. You should study Unit 17 on capacitor action in a circuit, so that you will understand its purpose. The capacitor serves two useful functions. First, when the points open, we know that an arc will be created across the points. Refer to Project 7. The capacitor will absorb this electrical energy and eliminate the arc across the points. This causes a more rapid change in the magnetic field and consequently more efficient operation of the induction coil. Secondly, the charged capacitor tends to reverse the flow of current through the coil, when the points open. This makes the magnetic field disappear very rapidly and again makes a more effective induction coil. The capacitor used in this project is a .1 mfd paper capacitor. You may wish to try other values and observe the effects.

QUIZ — PROJECT 8

1. The two coils of the induction coil are known as ________ and ________.
2. The voltage induced in the secondary is proportional to the ________.
3. Why can smaller wire be used in the secondary coil? Explain.
4. State two purposes of the capacitor in the circuit.
5. Would this induction coil work if it were supplied by a 6V bell transformer and the points were shorted together? Explain.
6. Ask your teacher to show you an automotive ignition coil. Ask her or him to show you the breaker points in a distributor. Draw a diagram of an automotive ignition system, using only one spark plug. Compare your drawing to the diagram shown in Fig. 18-30.

PROJECT 9 OSCILLATING WIG-WAG MOTOR

The wig-wag motor shown in Figs. 18-31 and 18-32 is an amusing and fascinating project which you can build. It is also very useful as a moving pointer to attract attention to a display. You will have a chance to test your construction skills and your understanding of electricity as you make this project.

Again you are not encouraged to build the motor exactly as shown in Fig. 18-31. Use your own imagination and the materials on hand.

The action of the motor is produced by the action of the coil. Therefore, the magnetic coil

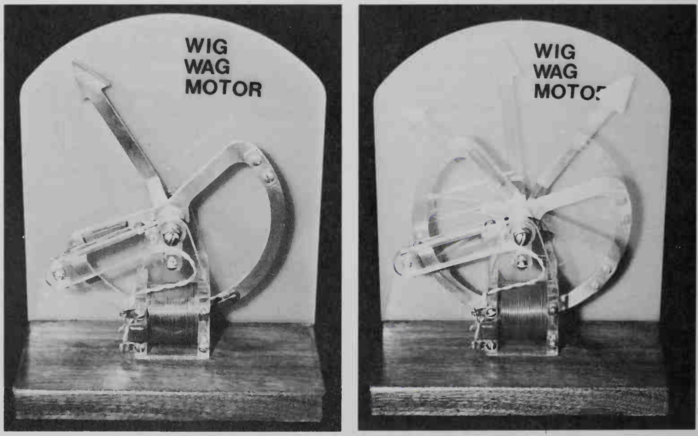


Fig. 18-31. Left. The completed Oscillating Wig-Wag Motor. Right. Strobe photo of wig-wag motor in action.

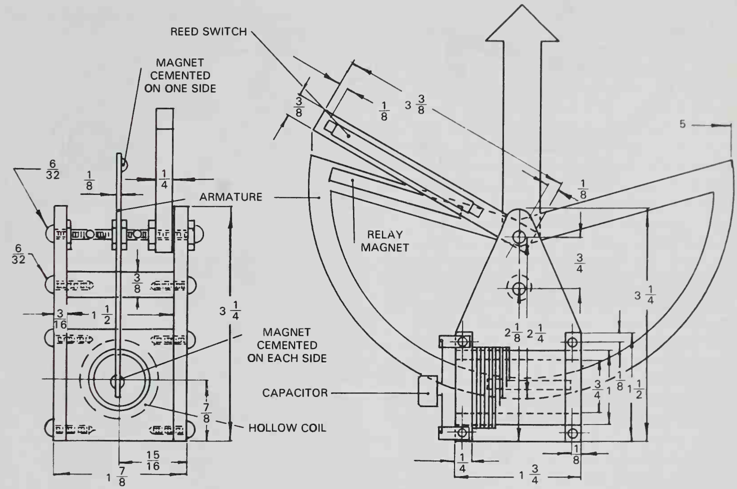


Fig. 18-32. Dimensions of wig-wag motor.

must be turned on at exactly the right time and remain on only long enough to keep the pointer moving back and forth. This is called TIMING. Similar adjustments are also made on the engine in the automobile.

Sliding brushes or contacts could be used, but this one uses a REED RELAY which is activated by a small permanent magnet on the swinging pointer. Each time the magnet passes the relay, it closes the coil circuit and pulls the core downward and into the coil. To improve the action of the motor we used permanent magnets for the moving core in the coil. Be sure the polarity is correct. The magnetic field of the coil must attract the magnets. See Fig. 18-32 for the dimensions.

CONSTRUCTION HINTS

1. The base and the back of the motor can be made of wood or plastic. You decide on the size.
2. The coil consists of four layers of #22 enameled wire wound on a hollow plastic spool. The hollow center should be about 3/4 inch in diameter to allow free movement of the core.
3. The swinging armature was cut from 18 gauge aluminum, Fig. 18-33. Supports for the bearings are also plastic and the armature shaft is made from 10-32 nuts and bolts.
4. For the core, a permanent magnet is cemented on each side of the flat aluminum armature. Only one magnet is needed to trigger the reed relay.
5. Note that a small .1 μF capacitor is wired across the relay points to prevent sparking and to increase life.
6. The motor is powered by one 1.5 volt D cell mounted in the rear.
7. The arm on which the reed relay is mounted is movable so that TIMING adjustments can be made.
8. The circuit diagram is quite simple and will

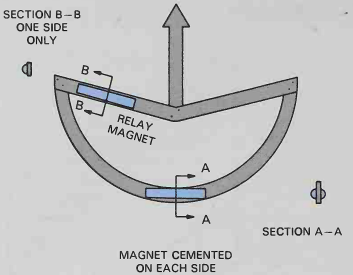


Fig. 18-33. The experimental motor has an armature made of flat 18 gauge aluminum. Note placement of little magnets for core and triggering the reed relay. No dimensions are specified. Design it by using available materials.

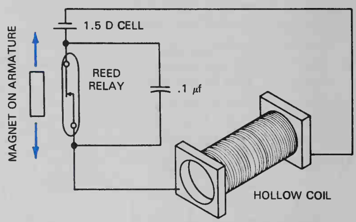


Fig. 18-34. The electrical circuit for the wig-way motor.

be found in Fig. 18-34.

9. The general outline for the armature is sketched in Figs. 18-32 and 18-33.

Small magnets are available at most hardware stores. This project used 3 each #773 DRITZ magnets from JOHN DRITZ & Sons, New York, N.Y. 10001.

PROJECT 10 TWO-POLE MOTOR

There are many types and kinds of motors. Some operate on direct current, while others use alternating current. The motor converts electrical energy into mechanical work. The extensive use of motors at home and in industry suggests that an elementary understanding of such a device is essential to our education in electricity.

The theory and operation of the motor has been explained in Unit 10. However, as you construct this small motor, an awareness of the underlying principles of operation will be helpful.

Again a motor may be built in many ways. If you wish to build one like the illustration in Fig. 18-35, follow the plans carefully. It would be better if you adapted the materials at hand and constructed the motor on your understanding of the principles.

CONSTRUCTION HINTS

1. The motor illustrated in Fig. 18-35 was built on a wooden base about 4 × 5 in. but any size base of a suitable material will be satisfactory. Sand and finish this base in an approved manner, which will demonstrate your skill as a good technician.
2. The armature may be made first. Refer to drawing in Fig. 18-36. Secure a 5/16 hexagon nut. Lay out, center punch, and drill in two opposite flat sides of the nut a hole the exact size of a 20d. nail. Cut two 20d. nails to length of about 1 1/4 inch. Place two 3/4 in. fiber washers over each nail and force the nails into the holes drilled in the nut. If the nails fit too loosely, place the end on an anvil and hit it a sharp blow with a hammer. This will knock the nail slightly out-of-round and will cause the nail to fit tightly in the holes.
3. Spread the two fiber washers on the nails and place a layer of tape over the nail between the washers. Starting at the center

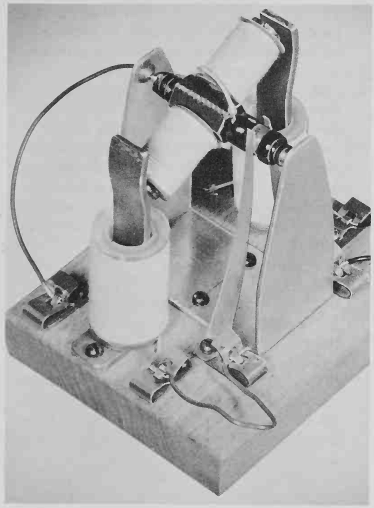


Fig. 18-35. A two-pole ac motor which may be connected as a series or shunt wound motor.

by the nut, wind the individual coils. Wind about six layers of #22 cotton covered or enamel covered wire on each armature coil. Both coils should be wound in the same direction. They are connected together in series. It is not necessary to cut the wire between the coils. Wind one coil and bring the wire across the nut to the start of the second coil and continue winding.

4. The armature shaft is made by cutting the heads from a 5/16 × 1 1/4 and a 5/16 × 3/4 bolt. Place the bolts in a lathe or drill press, and file the unthreaded ends to a cone-shaped point. These points will be the motor bearings. One bolt is screwed half way into the nut from one side and the other bolt is screwed into the other side. Jam the two bolts together by tightening with pliers or pipe wrench.
5. The threaded portion of each bolt is now wrapped with a layer of plastic tape for insulation and appearance. The commutator sections are made by sawing a piece of 1/4 in. copper tubing lengthwise. The two copper pieces are placed over the longer side of the armature shaft. If the fit is not tight, build up the shaft with another layer of tape. Solder neatly each of the two wires coming from the armature coils to a commutator section. Secure the sections in place by wrapping the ends with tape. Be sure that a space remains between the sections. About one quarter inch should be left untaped in the center, so that brushes may make contact with the commutator. See Fig. 18-37. Important: The placement of the commutator sections in relation to the coils must be correct. See Fig. 18-38.
6. The motor frame is made with 16 ga. aluminum bent in a U-shape, Fig. 18-39. The armature is placed in position between the uprights of the bracket. Lay the bracket on its side on the bench and hit it a blow with a hammer. The cone-shaped points

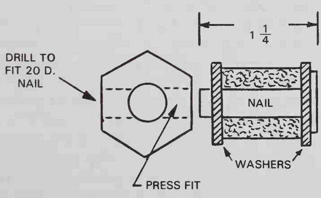


Fig. 18-36. The nails are forced into the holes in the nut to form the cores of the armature.

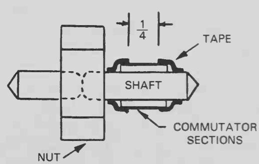


Fig. 18-37. The two commutator sections are fastened to the shaft with platic tape.

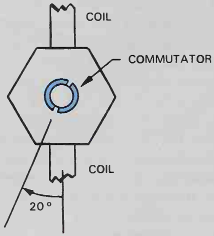


Fig. 18-38. Commutator sections are turned to an angle of about 20 degrees from center line through coils.

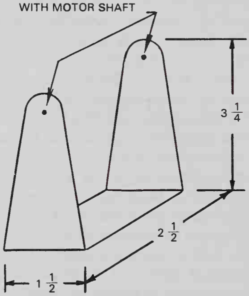


Fig. 18-39. The motor frame.

will make indentations in the aluminum and form the bearing holes for the revolving armature. Fasten the bracket and armature assembly to your base with round head wood screws.

7. The field poles of the motor are made by shaping two pieces of 1/8 × 5/8 × 4 1/4 in. iron. Three-quarters of an inch from one end, bend the iron to a right angle. Drill a hole and mount the angles to the wooden base. Your armature should revolve freely between these poles and in line with them, yet not touch them. Some shaping and bending may be necessary. A slight curvature to conform to the revolving armature will make your motor more powerful.
8. The field coils are wound on spools 1 in. diameter by 1 3/4 in. long. A 5/8 hole is drilled through the center of the spools so they will slide over the field poles. The coils are wound with six layers of #22 cotton or enamel covered wire. The ends of each coil are connected to Fahnestock clips fastened to the base on each side of the coil, Fig. 18-40.
9. The brushes are made of 22 ga. brass (other materials and thicknesses may be used) 3 1/2 in. long and about 1/8 in. wide. Bend a right angle on one end of each brush, drill and fasten to base with round head wood screw. A Fahnestock clip is also fastened to each brush with the same mounting screw. The brushes should line up and make contact with the commutator sections. Slight bending adjustments may be necessary.

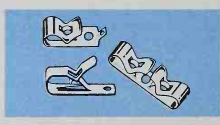


Fig. 18-40. Fahnestock clips. (General Cement Mfg. Corp.)

10. Your motor is now ready for a trial operation. The individual Fahnestock clips for each field coil and the brushes allow you to connect the motor as a series or shunt wound motor, and also provide a method of reversing the motor rotation. Connect a jumper wire between the two field coils, so that the outside winding on one coil is connected to the outside winding of the second coil. Connect the remaining terminal of each field coil to the brush terminals by jumper wires. Attach a 6V source across the brush terminals. Your motor should run if you have followed instructions carefully.

It may be necessary to turn the armature slightly to start its rotation.

PROJECT 10
TWO-POLE MOTOR EXPERIMENTS

Refer to the diagram in Fig. 18-41 for connections and lead identifications for these experiments.

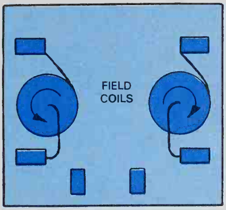


Fig. 18-41. Two-pole motor connections. Also refer back to Fig. 18-35.

1. Connect as series motor. C to A, B to X. Apply voltage to D and Z.
   A. The motor runs clockwise or counterclockwise?
   B. Connect wires on schematic diagram for the series wound motor.
2. Connect as shunt motor, X to B, A to C, D to Z. Apply voltage across brushes X and Z.
   A. The motor runs clockwise or counterclockwise?
   B. Draw another schematic diagram like that of experiment 1 showing the connections for the shunt motor.
   C. Reverse the connections of battery on terminals X and Z. The motor runs clockwise or counterclockwise?
   D. When connections are made as in question C, the field pole with coil AB is a north or south pole?
      The field pole with coil CD is a north or south pole? (Hint: Use left-hand rule.)
3. Reverse polarity of fields in the shunt motor. Connect A to X, C to Z, and A to D. Apply voltage across X and Z. Does the motor run clockwise or counterclockwise?
4. Connect the motor in the following manner. C to B, X to A, Z to D. The motor runs clockwise, counterclockwise, does not run? Explain.

PROJECT 11 ELECTRIC ENGINE

The easy-to-build engine shown in Fig. 18-42 demonstrates the conversion of electrical energy into reciprocating motion, and then to rotary motion by means of a connecting rod and flywheel. The engine operates by the solenoid action of the coil, which is energized when the breaker points close. The breaker cam on the end of the flywheel shaft should be made adjustable so that the engine may be "timed." For proper operation the points should close early on the inward stroke of the solenoid piston. The points must open just before the maximum inward stroke. The kinetic energy stored in the flywheel carries the engine through its no-power stroke. Fig. 18-43 shows the timing for proper operation.

CONSTRUCTION HINTS

1. Dimensions and exact construction are unimportant in this project. Think the problem through and design your own base and mechanical parts.
2. The coil is wound with six layers of #20 enamel covered wire over a 3/8 copper tubing core.
3. In Fig. 18-42, the coil ends have been shaped from small blocks of wood.
4. For the flywheel, a section 1/4 to 1/2 in. long may be hacksawed from 1 1/2 — 2 in. round steel bar. A lathe may be used for facing the flywheel.
5. Shaft supports may be bar iron or

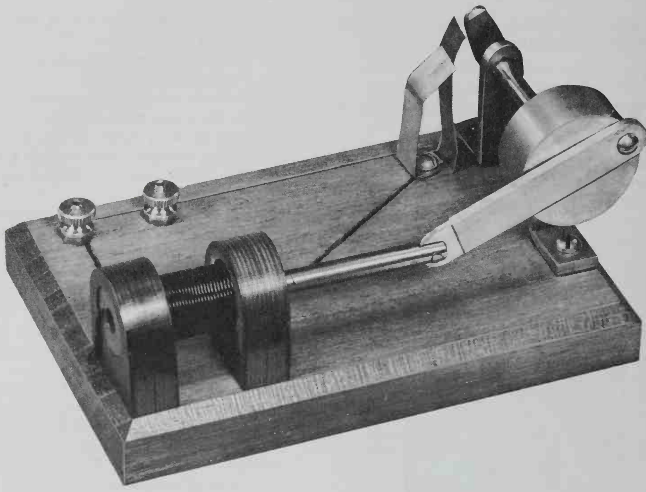
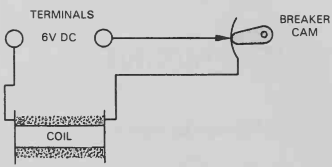


Fig. 18-42. An electric engine which demonstrates solenoid action and engine timing.



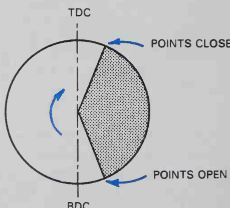


Fig. 18-43. Left. Connection diagram for electric engine opening and closing in relation to top dead center. Right. A TIMING diagram showing top dead center (TDC), bottom dead center (BDC), and timing points.

aluminum.

6. The cam is fitted snugly to the shaft, but you should be able to rotate it for proper timing of the engine.
7. The breaker points are constructed of 24 ga. brass.
8. Connections are diagramed in Fig. 18-43.

PROJECT 12 POWER OUTLET BOX

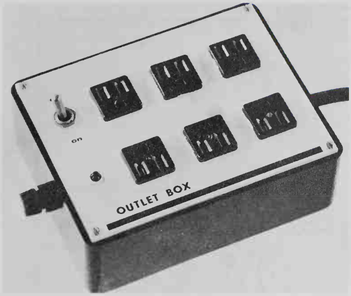


Fig. 18-44. Power outlet box.

This project may be one of the most useful electrical devices that you build. Everyone needs extra outlets from time to time. Also, it is a simple project to construct. See Fig. 18-44.

Refer to the parts list and Fig. 18-45 showing the schematic. After you obtain a plastic case with an aluminum cover, drill the holes for the grounded receptacles (outlet). You may need to file the holes to fit the shape of the receptacles. Drill the holes for the line cord, fuse, pilot lamp, and switch. Mount the outlets and other components. Wire the outlet box. All outlets are wired in parallel. Note that the green lead is ground. Connect the white line cord conductors together. Connect all the black conductors together.

PARTS LIST — POWER OUTLET BOX

SW_1 — SPST Toggle Switch, Heavy Duty @ 10A, 125V ac
J_1 - J_6 — Receptacles, 3-wire Grounding Type Convenience Outlets, 110V @ 15A, SNAP-in type
NL_1 — Neon Indicator Glow Lamp with Built in 100K Resistor, 110V ac
FUSE — 10 amp
FUSE HOLDER
PLASTIC CASE
ALUMINUM COVER FOR PLASTIC CASE
LINE CORD — (Grounded)
MISC: — Decals, Wire Nuts

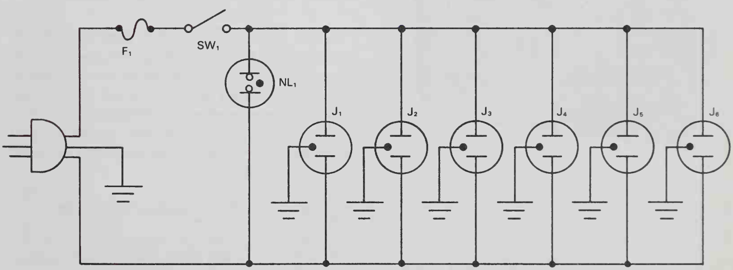


Fig. 18-45. Schematic for power outlet box.

PROJECT 13 CONTINUITY TESTER

The simple continuity tester project shown in Fig. 18-46 will help you determine opens or shorts in electrical circuits. It can be used to test low voltage circuits with power. Also, it is self powered and can be used to test continuity.

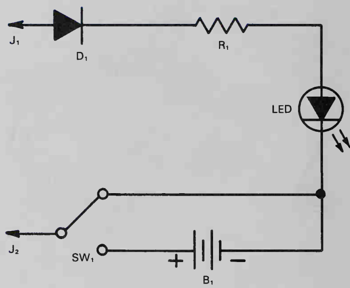


Fig. 18-47. Schematic for continuity tester.

Fig. 18-46. Continuity tester.

To operate the continuity tester, place the switch in the "battery" position. Touch the two leads together and the LED should glow. This indicates a complete circuit and in this mode it can be used to test whether switches are on or off (or faulty). Also, fuses can be tested to see whether they are open or not. Suspect broken wires in a circuit can also be checked for continuity with this testing device.

In the "check" continuity position, the circuit relies on external voltage for operation. In this mode, the continuity tester can be used to test batteries from about 4.5 volts to 15 volts. Be sure to connect the probes in the circuit with the correct polarity. It can also be used to test whether low voltage dc self-powered circuits are open or shorted.

Refer to the parts list and Fig. 18-47 of the schematic for the continuity tester. Note that the battery is used in one position of switch (S_1). In the other position of S_1 the continuity tester requires the power of the circuit to be tested. Observe the correct polarity of the light emitting diode when you wire the circuit.

PARTS LIST — CONTINUITY TESTER

R_1 — 470 ohm, 1/4 watt resistor
LED — Light emitting diode (Max, forward current: 30 mA; forward voltage 2.5V)
D_1 — Diode, Silicon switching diode (t_{rr} = .004$_{\mu s}$) (RCA SK3100)
B_1 — 9V Transistor battery.
SW_1 — SPDT switch.
MISC: — Plastic box with cover, wire, test leads with probes or alligator clips on one end and banana plugs on other end.

PROJECT 14 AUTOMOTIVE BATTERY CHARGER

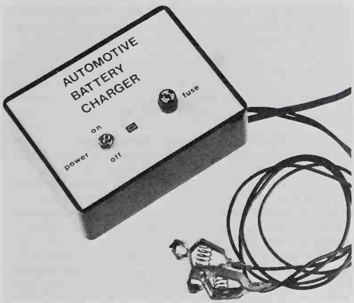


Fig. 18-48. Automotive battery charger.

Everyone that owns a car should have a battery charger. This inexpensive and useful project can charge a 12 volt automobile battery overnight, Fig. 18-48. It produces 1.5 amps of current which acts as a "trickle" charger. Refer to the parts list and Fig. 18-49 of the schematic for the automotive battery charger.

The automotive battery charger is very easy to use. Simply connect the "plus" clip of the charger to the positive lead of a car battery and the "minus" clip to the negative lead. Be sure that the battery has ample water in each cell before you begin charging. It is recommended that the charger be connected to the battery for a minimum of 6-8 hours in order that the trickle charge is effective. Be very careful that no one smokes or strikes a match around the battery since explosive hydrogen gas is given off during the charging process. Also do not try to "jump start" an automobile with this charger since a low output current (1.5 amp) is provided. This automotive battery charger is an excellent slow charging device for 12 volt batteries.

PARTS LIST — AUTOMOTIVE BATTERY CHARGER

SW_1 — SPST switch
NL_1 — 110V ac Neon pilot assembly (with built in resistor)
T_1 — Transformer, Power, 110V ac Primary; 12.6V ac @ 3 amp secondary, center tapped
D_1 - D_2 — Silicon Rectifiers, 3 amp @ 50 PIV
F_1 — Panel mount fuse holder and fuse (3 amp)
CLIPS #1 & #2 — Heavy duty battery clips
CASE — Plastic with aluminum cover
MISC: — Line cord and plug; heavy duty cable for clips #1 & #2; grommets; decals

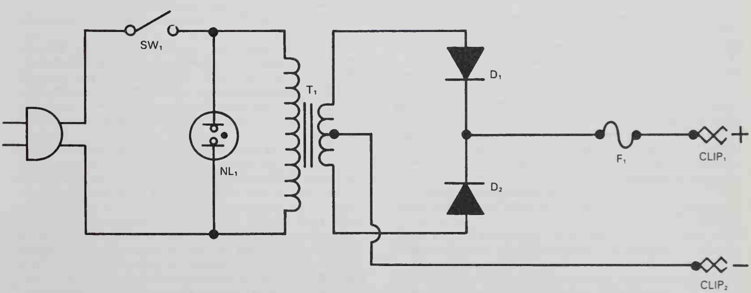


Fig. 18-49. Schematic for automotive battery charger.

GLOSSARY

ALTERNATING CURRENT (ac): Current of electrons that moves first in one direction and then in the other direction.

AMMETER: Meter used to measure current. Connected in series in the circuit.

AMPERE: Unit for current. One ampere equals one coulomb (6.24×10^{18} electrons) passing given point in conductor in one second.

AMPERE-HOUR: Unit of measurement of the capacity of a cell or battery. A battery with one hundred ampere-hours capacity can theoretically supply one hundred amperes of current for one hour, or one ampere for one hundred hours.

AMPERE-TURN: Unit of measurement of magnetomotive force. Represents the product of amperes times the number of turns in coil of an electromagnet.

AMPLIFICATION: Ability of component or device to increase the magnitude of an almost infinitely small ac electrical signal.

ARMATURE: Movable part of generator or motor, usually the rotating windings and magnets. In relay or buzzer, the armature is the movable arm in the magnetic field.

ATOM: Smallest particle of element that can exist without losing its identity.

ATOMIC NUMBER: Number of protons in nucleus of given atom.

ATOMIC WEIGHT: Mass of nucleus of an atom in reference to oxygen, which has a weight of 16.

AUTOTRANSFORMER: Transformer with a common primary and secondary winding.

AVERAGE VALUE: Value of alternating current or voltage of sine wave form. Found by dividing the area under one alternation by the distance along the X axis between 0° and 180°. ($E_{AVG.} = .637 \times E_{MAX}$)

BASE: Thin section between emitter and collector of a transistor.

BATTERY: Group of two or more cells connected together. A single cell is sometimes called a battery.

BRUSH:Sliding contact, usually of copper or carbon, which rubs on the commutator or slip ring of the generator or motor. Through brush, electrical connection is made to revolving armature.

CAPACITANCE: Inherent property of electric circuit that opposes change in voltage.

CAPACITIVE REACTANCE (Xc): Opposition to ac current as result of capacitance.

CAPACITOR:Device which possesses capacitance. A simple capacitor consists of two metal plates separated by insulator.

CELL: Single unit consisting of receptacle containing a negative electrode, a positive electrode, and the electrolyte. The cell generates a voltage by chemical action.

CHARGE: Process of building negative potential on one plate of capacitor and positive potential on the other plate.

CIRCUIT BREAKER: Automatic safety device, usually thermally or magnetically operated, which automatically opens an overloaded circuit.

COLLECTOR: Semiconductor section of transistor which ccllects the majority carriers.

COMMUTATOR: Group of bands providing connections between armature coils and brushes used for reversing direction of an electric current.

COMPOUND WINDING: Method of winding motor or generator in which the windings are in series and in parallel, either interacting against each other or reinforcing each other.

CONDUCTANCE: Ability of wire or component to transmit or conduct electric current. It is measured in siemens. (Letter symbol for conductance is G.)

CONDUCTOR: Material which readily transfers electrical energy. It has a very low resistance to electric current flow.

COPPER LOSSES: Heat losses in motors, generators, and transformers as a result of resistance wire.

COULOMB: Quantity of electrons (6.24×10^{18} or 6,240,000,000,000,000,000 electrons).

COUNTER EMF (cemf): Voltage induced in conductor moving through magnetic field which opposes the source voltage.

COUPLING: Percentage of mutual inductance between primary and secondary coils of transformer.

CURRENT: Transfer or movement of electrical energy in conductor by means of electrons moving constantly and changing positions in a vibrating manner.

CYCLE: One complete reversal of alternating current from positive to negative and back to starting point.

D'ARSONVAL METER: Stationary-magnet moving coil meter.

DEFLECTION: Moving of meter indicating pointer. The limit of a scale on a meter would be at full scale deflection.

DIELECTRIC: Nonconducting material, such as an insulator.

DIODE: Two-terminal device which will conduct electricity more easily in one direction than in the other direction.

DIRECT CURRENT (dc): Current of electrons that flows in one direction only.

DOPING: Adding an impurity to semiconductor material.

E: Symbol for voltage in Ohm's Law.

EDDY CURRENT LOSSES: Induced currents flowing in a body such as core or armature by variation in magnetic flux.

EFFECTIVE VALUE: Value of alternating current of sine wave form. It has the equivalent heating effect of direct current. Sometimes referred to as the root-mean-square (rms) value. ($E_{EFF} = .707 \times E_{MAX}$)

ELECTRIC POWER: Rate of doing electrical work.

ELECTRICITY: Movement of electrons in a conductor.

ELECTRODE: Elements in a cell.

ELECTROLYTE: Acid solution in a cell.
ELECTROMAGNET: Magnet formed by winding several turns of wire around an iron core. The polarity of the electromagnet depends upon direction of current flow in the coil.
ELECTROMOTIVE FORCE (EMF): Force that causes free electrons to move in conductor. Unit of measurement is the volt.
ELECTRON: Negatively charged particle of electricity.
ELECTROSCOPE: Laboratory device used to detect small electrical charge. Consists of two small metal foil strips suspended in glass bottle. Charged foil strips repel each other.
ELECTROSTATIC FIELD: Static field of force existing around charged body or terminal.
EMITTER: Semiconductor section in either P or N type transistor which emits majority carriers into the interelectrode region.
ENERGY: Capacity for doing work.
EQUIVALENT RESISTANCE: Expresses the resistance of a network of resistors. Electrically speaking, an equivalent resistor is one resistor that equals the sum of several resistors in the circuit.
FARAD: Unit of measurement of electrical capacitance. Named in honor of Michael Faraday.
FIELD MAGNETS: Electromagnets which produce the field of motor or generator.
FIELD POLES: Iron magnets in field circuit of motor or generator around which the field windings are wound.
FILTER: Circuit that changes the ripple in pulsating dc to pure dc.
FLUX: Magnetic lines of force running between the poles of magnet.
FORWARD BIAS: External voltage applied in conducting direction of a PN junction. The positive terminal is connected to the P-type region and the negative terminal to the N-type region.
FREQUENCY: Number of complete cycles per second measured in hertz.
FUSE: Safety protective device made of metal with low melting point which will melt and open the circuit if current flow in circuit exceeds the rating of the fuse.
GAUSS: Unit of measurement for intensity of a magnetic field.
GENERATOR: Device which converts mechanical energy into electrical energy.
HENRY: Unit of measurement for inductance.
HERTZ: Unit of fequency measuring cycles per second.
HOLE: Positive change, space left by a removed electron.
HORSEPOWER: Unit of measurement of work accomplished when 33,000 pounds are moved a distance of one foot in one minute, or 550 foot pounds per second. Electrically, one horsepower equals 746 watts.
HYDROMETER: Bulb type instrument used to measure specific gravity of a liquid.
HYSTERESIS: Retardation or resistance to the changing magnetic field in core material of generator, motor, or transformer. Molecular friction.
I: Symbol for current in Ohm's Law.
IMPEDANCE (Z): Total resistance to flow of ac current as result of resistance and reactance.
INDUCTANCE (L): Property of a coil which offers resistance to a varying current.
INDUCTOR: Coil; component with the properties of inductance.
INSULATOR: Material or substance which has high resistance to flow of electic current.
INTEGRATED CIRCUIT (IC): Fabrication process in which many electronic circuits and devices are formed on single silicon chip.
ION: Atom which has either lost or gained an electron and becomes either positively or negatively charged.
IONIZATION: Process of breaking up atoms into ions. Atom is ionized when it has lost or gained one or more electrons.
IR DROP: Voltage loss across resistive component in circuit. Voltage equals current times resistance. $E = I \times R$.
IRON VANE METER: Meter based on principle of repulsion between two connective vanes placed inside a solenoid.
JOULE: Unit of measurement of electrical work or energy. Energy used when one ampere of current flows through one ohm of resistance for one second.
KILO: Prefix meaning one thousand.
LAMINATIONS: Thin sheets of metal used in cores of transformers, motors, and generators to reduce eddy currents.
LAW OF CHARGES: Like charges repel; unlike charges attract.
LC TIME CONSTANT: Time period required for voltage across inductor or capacitor to increase to 63.2% of maximum value or to decrease to 36.7% of maximum value. Time (in seconds) = L in henrys divided by R in ohms.
LENZ'S LAW: Induced emf in circuit is always in such a direction as to oppose the effect that produces it.
LIGHT EMITTING DIODE (LED): Solid state device that emits light if current is passed acorss the P-N junction.
LOCAL ACTION: Defect in voltaic cells caused by impurities in the zinc, such as carbon, iron, and lead.
MAGNETIC FIELD: Imaginary lines along which magnetic force acts. The lines externally leave from the N pole and enter the S pole, forming closed loops.
MAGNETISM: Invisible force of magnet which causes it to attract iron objects.
MAGNETITE: Magnetic iron ore.
MAGNETOMOTIVE FORCE: Magnetic pressure as result of the number of turns in magnet coil and current flowing in the coil. Measured in gilberts.
MEGA: Prefix meaning one million.
METER: Instrument used to measure electrical quantities.
MHO: Unit of measurement of conductance. (New term for MHO is SIEMEN).
MOLECULE: Smallest part of a compound, made by the combination of two or more atoms.
MOTOR: Device which converts electrical energy to rotating mechanical energy.
MULTIMETER: Combination volt, ampere, and ohmmeter. A switch changes the leads to the desired meter and range.
MUTUAL INDUCTANCE: When two coils are located so the magnetic flux of one coil can link with turns of the other coil. The change in flux of one coil will cause an EMF in the other coil.
NEUTRON: Uncharged particle of electricity found in nucleus of atom. It has the same mass as the hydrogen atom.
NORTH POLE: Concentration of magnetic lines of force at one end of magnet. Opposite end and polarity from the south pole.
NUCLEUS: Core or center of an atom.
OHM: Unit of measurement of electrical resistance.
OHMMETER: Meter used to measure resistance in ohms.
OHM'S LAW: Mathematical relationship between current, voltage, and resistance.
PARALLEL: Method of connecting circuit components side by side, with the ends of each component connected together. Current flowing in circuit divides among the branches of parallel circuit.
PENTAVALENT: Semiconductor impurity having five valence electrons.
PERIOD: Time for one complete cycle.
PERMEABILITY: Ability of substance to conduct a magnetic field.
PHOTORESISTIVE CELL: Device which will change internal resistance under influence of light intensity.
PHOTOVOLTAIC CELL: Cell which generates voltage at the

junction of two materials when exposed to light.

PIEZOELECTRIC EFFECT: Property of certain crystalline substances changing their shape when an EMF is impressed upon the crystal. This action is also reversible.

POLARITY: Particular state of charged body or terminal, either negative or positive, in respect to another body or terminal.

POTENTIAL DIFFERENCE: Difference in electrical pressure between two bodies or two points in a circuit, measured in volts.

PRIMARY: First coil of transformer or coil connected to power source.

PRIMARY CELL: Cell which cannot be recharged.

PRIMARY WINDING: Coil of transformer or the coil connected to the power source.

PROTON: Unit of positive electricity.

R: Symbol for resistance in Ohm's Law.

RC TIME CONSTANT: Time period required for voltage across capacitor in an RC circuit to increase to 63.2% of maximum value or to decrease to 36.7% of maximum value. Time (in seconds) = (in ohms) times C (in farads).

REACTANCE: Effect of inductance or capacitance in a circuit to the flow of an alternating current. Reactance is measured in ohms.

RECTIFICATION: Process of changing alternating current to direct current.

RELAY: Electromagnetic switch.

RELUCTANCE: Resistance to conducting a magnetic field.

RESIDUAL MAGNETISM: Magnetism remaining in material after magnetizing force is removed.

RESISTANCE: Quality of an electric circuit that opposes the flow of current. As resistance is overcome, heat is produced.

RESONANCE: Condition in electrical circuit containing inductance, capacitance and resistance, when the capacitive and inductive reactance are equal and cancelling each other out leaving only resistance in the circuit. Resonant frequency equals:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

when, f_r = resonant frequency. π = 3.1416. L = Inductance in henrys. C = Capacitance in farads.

REVERSE BIAS: External voltage applied to semiconductor PN junction to reduce flow of current across junction and thereby widen depletion region. The opposite of forward bias.

ROOT-MEAN-SQUARE VALUE: Effective value of alternating current or voltage.

SCHEMATIC: Chart or diagram showing arrangement and connection of various electronic parts using conventional signs and symbols.

SECONDARY: Second winding of a transformer.

SECONDARY CELL: Cell which can be reactivated or recharged by reversing the current flow through it which reverses the chemical action.

SECONDARY WINDING: Winding of transformer in which voltage is induced by primary. Output is taken from secondary coil.

SELF-INDUCTANCE: EMF is self induced when it is induced in conductor carrying current.

SEMICONDUCTOR: Conductor with resistivity in range between conductors and insulators.

SERIES: Number of circuit components connected in succeeding order or end to end, so that current flowing through one will flow through all of the components.

SERIES CIRCUIT: An electrical circuit with only one path for electrons to flow.

SERIES MULTIPLIER: Precision resistor connected in series with voltmeter to increase its range.

SERIES WINDING: Type of winding in motor where field carries the same current as the armature. (The winding is in series with the armature rather than in parallel with it.)

SHORT CIRCUIT: Direct connection across circuit which provides a zero resistance path for the current.

SHUNT: Component connected across a circuit or in parallel with another component.

SHUNT RESISTOR: Precision resistor connected in parallel to an ammeter to increase the range of the meter.

SHUNT WINDING: Type of winding in a motor in which the field circuit and armature circuit are connected in parallel.

SIEMEN: Unit of measurement of conductance. It is the reciprocal of resistance (one divided by the resistance).

SINE WAVE: Wave form of a single frequency alternating current.

SINGLE PHASE: Only one alternating current or voltage produced or used.

SLIP RINGS: Metal rings connected to rotating armature of generator. Brushes contacting these rings pick up the alternating current generated in the armature.

SOLAR: Pertaining to the sun.

SOLENOID: Coil wound to produce a magnetic field.

SOUTH POLE: The opposite polarity and end from the north pole of a magnet.

SPECIFIC GRAVITY: Weight of a liquid or substance as compared to an equal amount of water.

STATIC ELECTRICITY: Electricity at rest. Considered as a charge of electricity on a body, either negative or positive, compared to moving electricity called current.

STEP DOWN: To reduce from higher voltage to lower voltage, as in a step down transformer.

STEP UP: To increase to a higher voltage, as in a step up transformer.

SWITCH: Device for directing or controlling current flow in a circuit.

THERMOCOUPLE: Device made of two dissimilar metals which are welded together and will produce a voltage if they are heated.

TRANSFORMER: Device which transfers energy from one circuit to another by electromagnetic induction.

TRANSISTOR: Semiconductor device derived from two words, transfer resistor. An active semiconductor device, usually made of silicon or germanium, having three electrodes.

TRIVALENT: Semiconductor impurity having three valence electrons (acceptor impurity).

TUNE: Process of adjusting a radio receiver so that its resonance frequency is the same as that of the transmitting station.

VECTOR: Straight line drawn to scale, showing direction and magnitude of a force.

VOLT: Unit of measurement of electrical pressure or electromotive force. One volt will cause one ampere to flow through one ohm of resistance.

VOLTAGE: Same as electromotive force (EMF) and potential difference.

VOLTAGE DROP: The difference in voltage between two points in a circuit.

VOLTMETER: Meter used to measure voltage.

WATT: Unit of measurement of electrical power. It is the rate of work accomplished when one ampere of current flows at one volt pressure.

WATT-HOUR: Unit of electric energy measurement, equal to one watt per hour.

WATT'S LAW: Mathematical relationship between current, voltage, and power.

WORK: Scientifically speaking, work is accomplished when a force acts upon a body and moves it. Work is the product of force times distance.

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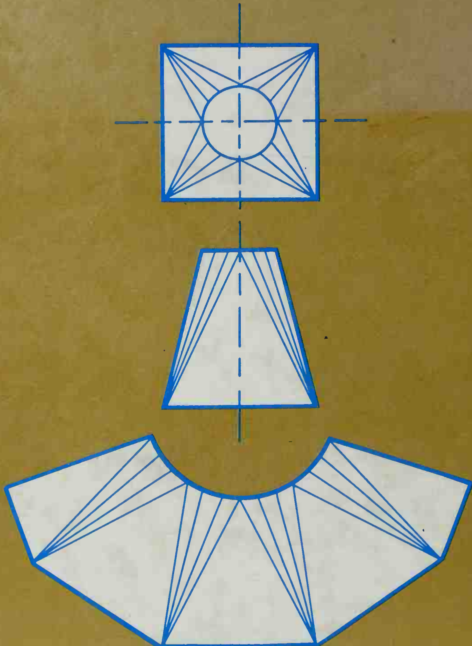

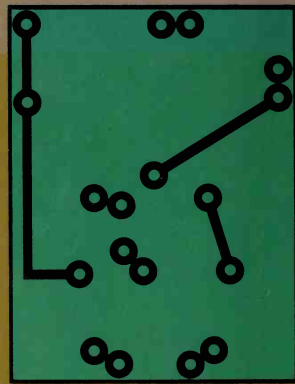

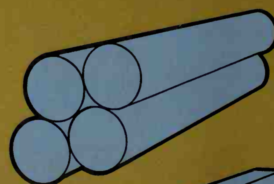

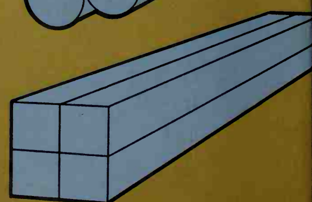

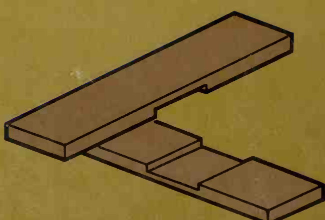

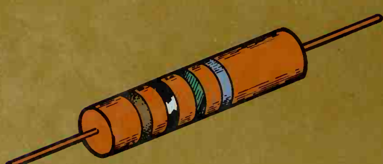

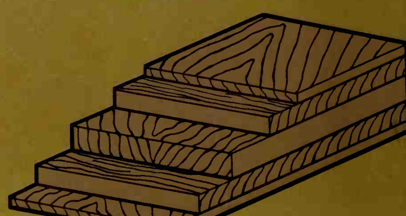

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